

# HYDROBIOLOGIA

ACTA HYDROBIOLOGICA, HYDROGRAPHICA ET  
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**HYDROBIOLOGIA** publishes original articles in the field of Hydrobiology, Limnology and Protistology. It will include investigations in the field of marine and freshwater Zoo- and Phytobiology, embracing also research on the Systematics and Taxonomy of the groups covered. Preliminary notices, polemics, and articles published elsewhere will not be accepted. The journal, however, contains reviews of recent books and papers.

Four numbers of the journal are published every year. Each number averages about 100 pages. Contributions must be clearly and concisely composed. They must be submitted in grammatically correct English, French, German, Italian or Spanish. Long historical introductions are not accepted. Protocols should be limited. Names of animals and plants must be given according to the laws of binominal nomenclature adopted at the recent International Congresses of Zoology and of Botany, including the author's name; it is desirable that the latter should be given in full. Measures and weights should be given in the decimal system. Every paper has to be accompanied by a short summary, and by a second one, written in an alternative language.

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## Felix Eugen Fritsch

F. E. Fritsch, Emeritus Professor of Botany at the University of London, died on May 23rd 1954 at the age of 75. He graduated at London and then went to Munich for three years where he proceeded to the degree of Ph. D. In 1902 he returned to London to take up an appointment in the university, on whose staff he remained for the rest of his employed life — his working life lasted almost to the day of his death. Taking charge in 1911 of the department of botany at East London College, later named Queen Mary College, he became University Professor in 1924. In 1932 he held a visiting Professorship at Stanford University in America and in 1938 he visited India and Ceylon, in the latter of which countries he had done some work in 1903. The Royal Society elected him a Fellow in 1932 and awarded him its Darwin Medal in 1950. He was also honoured by many foreign scientific bodies and was: Hon. Mem. Ind. Bot. Soc.; Hon. Mem. Soc. Roy. Bot. Belgique; Hon. Mem. Zool.-Bot. Gesellschaft, Wien; Corresp. Mem. Bot. Soc. America; Hon. Mem. K. Natuur. Genootsch. Dodonaea, Gent; Corr. Philadelphia Acad. Sci.; For. Mem. K. Fysiogr. Sällsk. Lund, Sweden; For. Mem. Norwegian Acad. Sci. and Letters, Oslo; For. Mem. Reg. Soc. Scient. Uppsala; For. Memb. Kon. Vlaamse Acad. voor Wetensch. lett. Sch. Kunst. Belgium.

Fritsch's first published work appeared in 1902 and thereafter for half a century scarce a year passed without some further contribution to science from his pen, a remarkable feat considering his other duties and the scope of his book „The structure and Reproduction of the Algae”, of which vol. 1 appeared in 1935 and vol. 2 in 1945. These works speak for themselves.

As a teacher, Professor Fritsch expounded general principles and the wide view with lucidity, but never allowed himself or his students to forget the importance of painstaking attention to detail — indeed his fame in other spheres was due to his ability to balance these two, for he never let himself either be carried away by flights of general fancy or be bogged down by excess of detail. His interest in teaching is reflected in the several text-books that he wrote, and his success in the number and standing of his old students throughout the country.

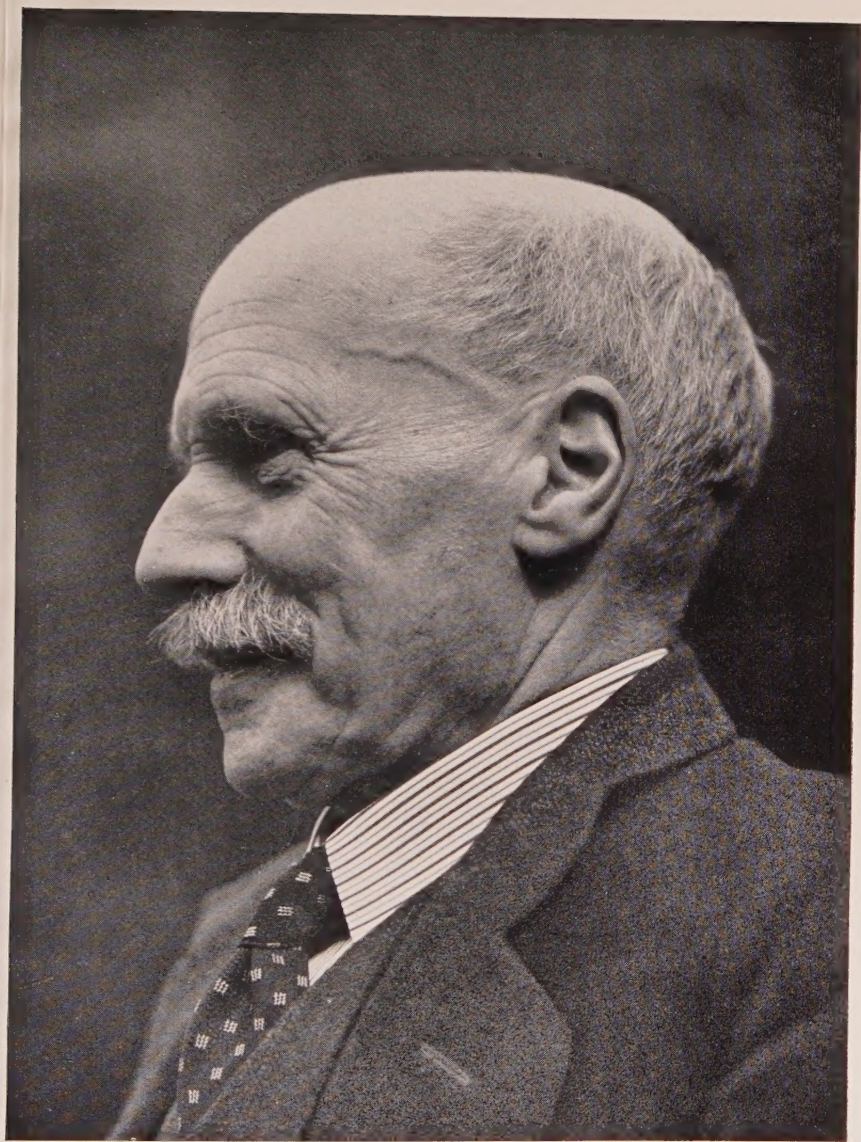
Few men seek to make a name in all three branches of university

work, research, teaching and administration; Fritsch was a master of each. For his sound and balanced judgment of affairs, his quick discernment of essentials, his ability to see points of view at variance with his own, and his equable temper, he was much in demand as a committee-man, and within a year of his death was still shouldering new responsibilities. After his retirement in 1948 he travelled sometimes several times a week to London from Cambridge, whither he had gone when this department moved there early in the war and where he had settled down, going up winter and summer as heedless of vagaries of the British climate, or of a frail body that had never been robust, as he had been a few years previously of the menace of the King's enemies. The British Ecological Society, The Botanical Section of the British Association for the Advancement of Science, The Linnean Society, and later, in 1953, the newly formed British Institute of Biology, and the International Association of Limnology, of which he was a founder member, elected him to the office of President. He was never a mere figure-head but quickly made himself familiar with the affairs of the society and kept in constant touch with the day-to-day run of business. The writer served under him for an all-too-short period as secretary of the last-named body and recalls vividly his keen interest, his quick grasp, his active help, and his wise advice. He gave advice freely, as the old do, but proffered it with the utmost modesty and was singularly unsistent that it should be followed. He had the virtues without the vices of old age.

In his presidential address to the British Association in 1927 he drew attention to the lack in Britain of any station for freshwater research of the kind that had been making notable contributions to science in several continental countries for several decades. The topic was taken up again in the following year and special discussions were held. The outcome was the foundation in 1929 of the Freshwater Biological Association, a delicate plant from the financial point of view. But the small group of distinguished men who had laboured to produce this seedling continued to devote much time to tending it. After a few precarious years, its roots tapped the rich nutritive layer of Government support and subsequent development was vigorous. Professor Fritsch, chairman of the council from the beginning, continued to take the greatest interest in all that went on and could devote his attention as seriously to some small domestic matter as to the programme of algological research. His death, the first gap in the ranks of the Old Guard, was felt keenly among his colleagues on the council and among the staff.

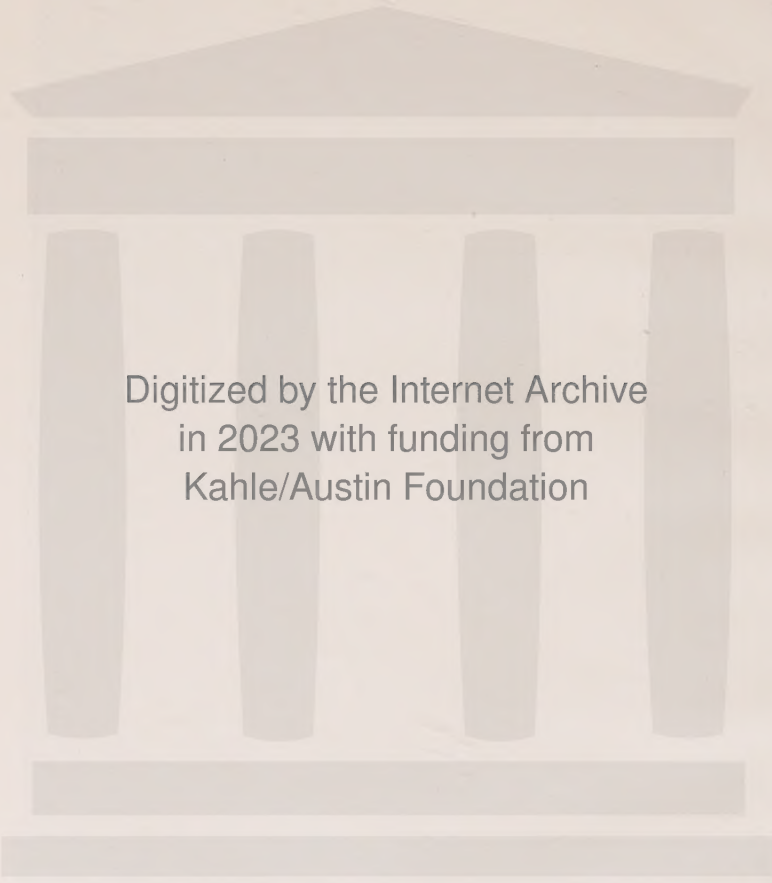
Fritsch's achievements compelled respect; his dauntless spirit in a frail body admiration; and his cheerful friendliness and kindness affection. He passed through life serene and unperturbed, and migh





Felix Eugen Fritsch





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be said to be one who was always looking for trouble — so that he might pour oil on the waters. No lame dog baulked by a stile was ever left on the wrong side if Professor Fritsch came within sight. Those who knew him out of working hours will rarely, as their minds roam back into the past, picture him for long without Mrs Fritsch, so cheerful, friendly and kind too. All who knew them will grieve for her in her solitude.

T. T. MACAN

Photograph by George Monkhouse F. R. P. S.

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# The plankton algae of three Ceylon Lakes<sup>1)</sup>

by

E. C. T. HOLSINGER

(with six figures in the text)

## INTRODUCTION

Little is known about the freshwater algae of Ceylon. In 1902 W. & G. S. WEST described algae collected mainly from rice-fields, while later LEMMERMANN (1907) gave an account of algae from two of the lakes. CROW (1923a) reported on the planktonic *Myxophyceae* and *Chlorophyceae* collected by F. E. FRITSCH in the lowlands and highlands.

The algae dealt with in this paper were collected between March 1949 and January 1952 from three lakes. viz., (a) Beira lake situated almost in the centre of Colombo, (b) Nuwara Wewa tank<sup>2)</sup> near the ancient town of Anuradhapura, almost at sea-level, and (c) Lake Gregory within the town of Nuwara Eliya, at an elevation of 1900 metres above sea-level. Samples of the water were collected from a boat some distance away from the banks and the plankton algae in them were obtained by sedimentation. Collections were made in all three lakes between March 1949 and March 1950 by the author, and between March 1951 and January 1952 in the Beira lake by Mr. H. VERE CLAASZ.

The algae in the samples are here dealt with from the taxonomic point of view. A later paper will discuss the causes for their observed distribution and periodicity.

In the following list of the plankton algae present new records for Ceylon are indicated by an \*, while the numbers after the species indicate the lakes in which they occurred — (1) Beira lake, (2) Nuwara Wewa tank, (3) Lake Gregory.

<sup>1)</sup> Part of thesis approved for the Degree of Doctor of Philosophy in the University of London.

<sup>2)</sup> A "tank" is a large artificial reservoir, built early in the Christian era for the irrigation of the lowland rice-fields.

- \* *Achnanthes minutissima* Kütz., var. *cryptocephala* Grun. (1—3)
- \* *Actinastrum Hantzschii* Lagerh., var. *elongatum* G. M. Smith (3)
- Aphanocapsa delicatissima* W. & G. S. West (3)
- \* *Aphanothece nidulans* P. Richt. (3)
- \* *Arthrospira platensis* (Nordst.) Gom. (1)
- \* *Chroococcus dispersus* (v. Keissler) Lemm. (1—3)
- \* *Chroococcus dispersus* (v. Keissler) Lemm. var. *minor* G. M. Smith (1—3)
- \* *Chroococcus limneticus* Lemm. var. *subsalsus* Lemm. (1—3)
- \* *Coelastrum microporum* Naeg. (3)
- \* *Cyclotella ceylonica* sp. nov. (1)
- \* *Cyclotella stelligera* Cl. & Grun. (3)
- Cylindrospermum* sp. (2)
- \* *Cymbella gracilis* (Rabh.) Cleve (3)
- Dinobryon cylindricum* var. *ceyonicum* Lemm. (3)
- Eunotia flexuosa* Kütz. (1—3)
- Eunotia lunaris* (Ehr.) Grun. var. *capitata* Grun. (1—3)
- \* *Frustulia rhomboides* (Ehr.) De Toni var. *saxonica* (Cl.) De Toni forma *undulata* Hust. (1—3)
- Lyngbya circumcreta* G. S. West (2)
- Lyngbya limnetica* Lemm. formae (1—3)
- Lyngbya* sp. *A* (1—3)
- Lyngbya* sp. *B* (1—3)
- \* *Melosira ambigua* (Grun.) O. Müll. (3)
- Melosira granulata* (Ehr.) Ralfs (1—2)
- Merismopedia tenuissima* Lemm. (1—3)
- Microcystis aeruginosa* Kütz. (1—3)
- Microcystis flos-aquae* (Wittr.) Kirchn. (1—3)
- Microcystis lamelliformis* sp. nov. (1—3)
- Microcystis marginata* (Menegh.) Kütz. (3)
- \* *Navicula cincta* (Ehr.) Kütz. forma *major* f. nov. (3)
- \* *Navicula radiosa* Kütz. forma (3)
- Oscillatoria Agardhii* Gom. forma (1—2)
- \* *Oscillatoria limnetica* Lem. forma (1—3)
- \* *Oscillatoria simplicissima* Gom. forma (1, 3)
- Oscillatoria tenuis* Ag. var. *natans* Gom. (3)
- Oscillatoria* sp. (1—3)
- Pediastrum duplex* Meyen var. \* *clathratum* (A. Br.) Lagerh. (3)
- Pediastrum duplex* Meyen var. \* *gracillimum* W. & G. S. West (3)
- Pediastrum tetras* (Ehr.) Ralfs (3)
- \* *Pinnularia tropica* Hust. forma (3)
- \* *Pseudanabaena catenata* Lauterb. (2)
- \* *Raphidiopsis curvata* Fritsch forma (2)
- Raphidiopsis* sp. (1)



- Scenedesmus abundans* (Kirchn.) Chod. var. \* *brevicauda* G. M. Smith (3)  
*Scenedesmus acuminatus* (Lagerh.) Chod. (1—3)  
 \* *Scenedesmus longispina* Chod. (1—3)  
*Scenedesmus quadricauda* (Turp.) Bréb. var. \* *parvus* G. M. Smith (3)  
 \* *Staurastrum brachioprominens* Boerg. forma (3)  
 \* *Staurastrum coarctatum* Bréb. var. *subcurtum* Nordst. forma (3)  
 \* *Staurastrum dejectum* Bréb. var. *patens* Nordst. forma (3)  
 \* *Synechocystis Revalekii* Ercogovic (1—3)  
 \* *Synedra affinis* Kütz. (3)  
 \* *Synedra nana* Meister (3)  
*Synedra ulna* (Nitzsch.) Ehr. (1—3)  
*Tabellaria fenestrata* (Lyngb.) Kütz. (3)  
 \* *Tabellaria flocculosa* (Roth.) Kütz. (3)

The three lakes exhibit certain similarities but differ in regard to the quantity of phytoplankton present and the distribution and periodicity of the major groups and of certain genera and species. Both in the Beira lake and in the Nuwara Wewa tank *Myxophyceae* are strongly represented but there is a striking difference in the size of the species present; in the latter 50% of the phytoplankton is constituted by species with very short and narrow filaments. *Myxophyceae* form 95% of the phytoplankton of Beira lake, the remainder being made up of *Cyclotella ceylonica* and a few other Diatoms, as well as of species of *Chlorococcales*. In Nuwara Wewa tank 87% of the plankton consists of *Myxophyceae*, the remainder being made up of *Melosira granulata* and other Diatoms, as well as of species of *Chlorococcales*. Lake Gregory presents a different picture; here 65% of the plankton consists of *Melosira ambigua* and only 30% of *Myxophyceae*, the remainder comprising Desmids (three species of *Staurastrum*) *Dinobryon cylindricum* var. *ceylonicum*, *Pediastrum duplex*, and species of Diatoms and of *Chlorococcales*.

The difference in elevation between Lake Gregory and the other two is correlated with temperature differences, the mean annual temperature of Lake Gregory being 15° C, that of the lowland lakes 27° C. The three lakes also differ in their surroundings; Beira lake is near certain insanitary parts of Colombo while Nuwara Wewa tank lies in a vast expanse of flat country covered mainly with jungle, and Lake Gregory occupies a mountain basin surrounded by tea plantations on the hill-sides. Other differences, such as the nature of the surrounding soil, the amount and distribution of rainfall, the rate of flow of the lake-water and differences in pH, conductivity and ammonia content of the water will be considered in a later paper.

## TAXONOMIC NOTES

### *Myxophyceae (Cyanophyceae)*

*Microcystis aeruginosa* Kütz. (Fig. 1). WESENBERG—LUND (1904) states that *Polycystis (Clathrocystis) aeruginosa* Kütz. is connected by numerous transitional stages with *Polycystis flos-aquae* Wittr. (*Microcystis flos-aquae* (Wittr.) Kirchn.). CROW's observations on Ceylon material (1923b; cf. also OSTENFELD, 1908) led him to similar conclusions. GEITLER (1932) is of the opinion that the two species *M. aeruginosa* and *M. flos-aquae* are probably only stages of a single one and DROUET and DAILY (1939) advocate their union; TEILING (1941), on the other hand, clearly distinguishes *M. aeruginosa* and *M. flos-aquae*.

In my Ceylon material *M. aeruginosa* is readily distinguishable from other species of the genus by the following characters:

- (i) The presence of a clearly defined and highly refractive layer in the bounding mucilage (Fig. 1, A—H), as pointed out by TEILING.
- (ii) The comparatively large size of the cells which tend to be distributed irregularly (Fig. 1, A—K).
- (iii) The crowding of the pseudovacuoles in the inner part of the chromatoplasm (Fig. 1, M).

Pseudovacuoles are a constant feature and they are also conspicuous in dividing cells. They are usually comparatively large and generally irregular in shape.

WESENBERG—LUND (1904) found that winter-forms of *M. aeruginosa* had a very thick mucilage-envelope which was often arranged in distinct layers. In my material, collected in different seasons, the peripheral layer of the mucilage-envelope is composed of two definite strata, readily distinguishable by suitable staining and by mounting the colonies in watery sepia or Indian ink when the inner refractive stratum stands out conspicuously and the outer is demarcated by the surrounding dark medium. The highly refractive inner stratum appears to have been observed by various observers, and it is presumably this which WESENBERG—LUND describes as "the sharp outline which the *Clathrocystis* colonies have". The wide zone of mucilage external to the refractive layer, which is seen in the Ceylon material, is not referred to by other observers. It is approximately  $5\ \mu$  thick, while the refractive layer seldom exceeds  $1\ \mu$ . In young colonies the outer stratum has a definite contour, but in older ones it tends to become diffuent at the surface and small algae and bacteria adhere to it, although they do not appear to penetrate into the inner layer. The two strata probably differ not only in refractive index and density, but also in chemical composition, since with suitable stains they assume somewhat different tints.



The colonies of *M. aeruginosa* assume diverse forms (Fig. 1 A—K). Very young ones are spherical or lens-shaped but as they enlarge they put out more or less spherical protrusions and lose their regular form; later these buds assume the form of elongate or irregularly



Fig. 1

*Microcystis aeruginosa* Kütz. A—G, I & K, colonies of diverse shapes; the continuous line marks the highly refractive stratum, and the dotted line the boundary of the outer layer of mucilage, as observed in colonies mounted in aqueous sepia. H, colony stained in very dilute aqueous Bismarck Brown; the dark line represents the refractive stratum of the mucilage. L, colony showing buds lying at different levels. M, a few cells, showing pseudovacuoles and cell-sheath.

shaped sacs. Tubular colonies (Fig. 1 K) are rare; in the figure a spherical bud has been abstricted at one end and another bud is in process of formation at the other end. The irregularly rounded colony

shown in Fig. 1, I, appears to be a bud that has separated completely from a colony like that shown in K. Occasionally a spherical colony enlarges without budding (Fig. 1, E), but generally it begins to bud when only 20  $\mu$  in diameter. The buds lie at different levels (Fig. 1, L) as is evident when colonies are examined in water in a shallow dish (see TEILING 1941, Figs. 1—7). It is difficult to understand why WESENBERG—LUND speaks of the colonies as "flat".

In my material the cells form denser clusters in different parts of the colony. This is noticeable even in young colonies and a regular disposition of cells is seldom observed in colonies over 4  $\mu$  in diameter. The tendency of the cells to form clusters is noticeable in *M. robusta* (CLARK) NYGAARD (see GEITLER, 1932) which lacks pseudovacuoles; were it not for this, it would have been attractive to speculate whether *M. robusta* might not be identical with *M. aeruginosa* in view of the definite outline of the colony and the comparatively large size of the cells.

Cells less than 5  $\mu$  in diameter were not found in the Ceylon material. Spherical cells were generally 5—6  $\mu$  broad, only occasionally reaching 7  $\mu$ . The largest (sub-spherical) cells, which appeared more or less oval in optical section, measured 8  $\times$  6  $\mu$ . TEILING gives the diameter of the cells as over 5  $\mu$ , G. M. SMITH (1920) that of the typical form as 3—4  $\mu$  and of the var. *major* as 5.5—6.5  $\mu$ . CROW gives the diameter as 3—7  $\mu$ .

In all three lakes *M. aeruginosa* was found together with *M. flos-aquae*.

*Microcystis flos-aquae* (Witttr.) Kirchn. (Fig. 2). There appears to be agreement that the mucilage-envelope of this species is hyaline, homogeneous, delicate and without a definite contour, implying that a highly refractive stratum, such as is conspicuous in *M. aeruginosa*, is absent. The edge of the envelope is recognisable in unstained material by the adhering foreign bodies. When suitably stained, the inner part is more deeply coloured, and the tint decreases gradually towards the edge (Fig. 2, D). The mucilage seems denser nearer the mass of cells, but no stratification is observable.

The youngest colonies are spherical (Fig. 2, A, 1 & 2), and may retain this shape up to a diameter of as much as 200  $\mu$ , although more often the spherical form is lost before that size is reached. Even some colonies of macroscopic dimensions may, however, possess an approximately circular outline so that they are more or less lens-shaped; that shown in Fig. 2, E & F measured 1.5  $\times$  1.3  $\times$  0.6 mm, and consisted of a very densely packed mass of cells, estimated as 34,000. Approximately spherical colonies, with a central region devoid of cells, are sometimes found. (Fig. 2, A, 9). Not uncommonly the



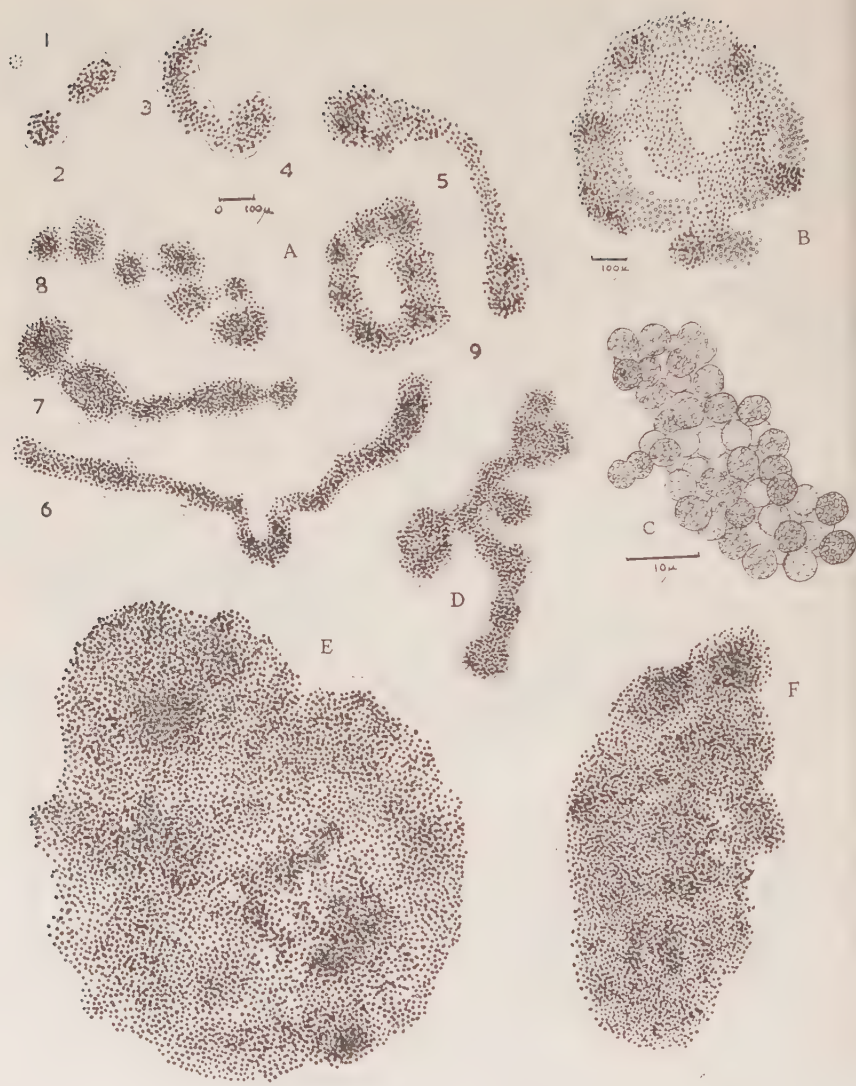


Fig. 2.

*Microcystis flos-aquae* (Wittr.) Kirchn. *A*, 1—9, colonies of diverse shapes, the dotted line indicating the limit of the mucilage-envelope when mounted in aqueous sepia. *B*, roundish clathrate colony. *C*, cells with pseudovacuoles. *D*, colony stained in dilute aqueous Bismarck Brown. *E* & *F*, surface- and side-views of a large colony.

colony consists of smaller, more or less spherical units (Fig. 2, A, 8). The cells are dark blue-green and more deeply pigmented than those of the other species. When preserved in 4% formalin, the dark grey colour which replaces the blue-green is likewise deeper than that of the other species. The density of arrangement of the cells in general varies directly with the size of the colony. In very young ones (Fig. 2, A, 1—3) it is not very dense, but as the colony grows in size the cells become more crowded. Dense packing of the cells is to be regarded as typical of *M. flos-aquae*. In optical section they appear circular, sometimes oval. Spherical cells measure 4—5  $\mu$  in diameter, oval ones,  $5 \times 6.5 \mu$ .

Pseudovacuoles are a constant feature of the cells of *M. flos-aquae*. They are more frequent in the outer part of the chromatoplasm, and this, coupled with the thinness of the cell-sheath, tends to make the cells appear irregular in outline.

*Microcystis lamelliformis* sp. nov. (Fig. 3).

*Diagnosis.* Colonies free-floating, spherical or irregular when very young, lamellate or lenticular when older and attaining macroscopic size, mucilage-envelope wide or not extending beyond the cell-mass. Cells spherical, diam. 3—4  $\mu$ , loosely aggregated, cell-sheath well marked; pseudovacuoles numerous, small and more or less rounded.

Very young colonies are spherical or of irregular shape (Fig. 3, A—C), but older ones are generally lamellate and occasionally lenticular, but never pellicular. The area of the colony shown in Fig. 3, D and E, was approximately  $1.3 \times 1.2$  mm, but its greatest thickness was only 0.15 mm and it was only ten cells deep in its thickest portion. The cells are always loosely aggregated and are less crowded in the larger than in the smaller colonies.

The colonial mucilage is invisible until stained, when it shows a definite margin (Fig. 3, F); this lies at a varying distance from the cell-mass being close to it or well separated from it in different parts of the same colony. The mucilage is homogeneous and is stained equally deeply throughout.

The cells (Fig. 3, F) are usually spherical, though somewhat elongate before division which occurs freely in the plankton. Spherical cells are 3—4  $\mu$  in diameter, oval cells up to 5  $\mu$  long. The cells tend to lie in short rows of 3, 4, 5 or more. The cell-sheath is well defined and stains somewhat differently from the general mucilage. Small, more or less rounded, pseudovacuoles are always present.

The lamelliform shape of the colony and the rather loose aggregation of the cells are characteristics which aid in the identification, particularly of the older colonies. The young spherical or irregularly shaped colonies (Fig. 3, A—C) might at first sight be confused with



small colonies of *M. flos-aquae*, but can be distinguished from the latter by the smaller size of the cells, their less compact aggregation, paler colour and smoother outline. Very young colonies are easily distinguished from those of *M. firma* (Bréb. et Lenorm.) which are pellicular and have distinctly smaller cells ( $0.8\text{--}2.3\ \mu$ ). The older colonies are characterised by the fact that their shape is lamellar or lenticular and not pellicular, and considerably larger with bigger cells.

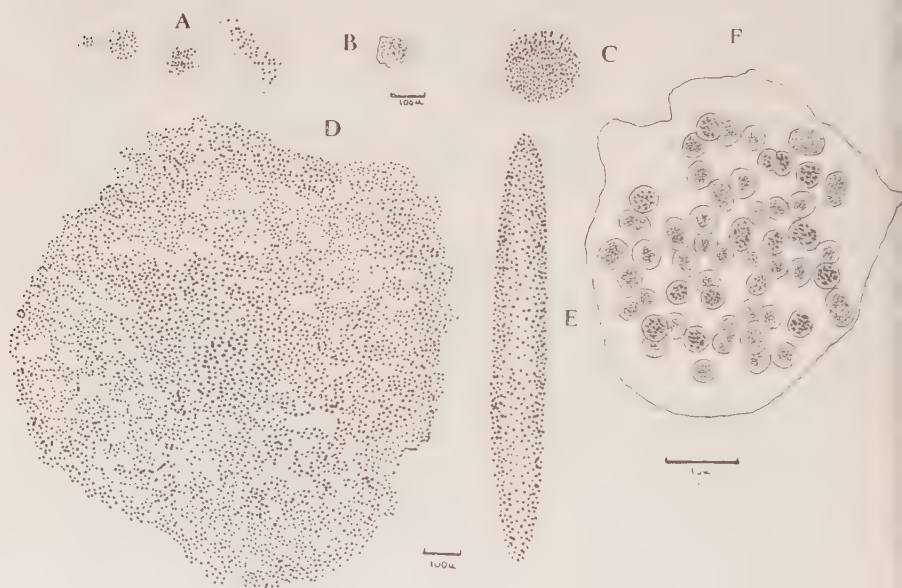


Fig. 3.

*Microcystis lamelliformis* sp. nov. A—C, small colonies. D, large colony in surface-view; E, the same in side-view. F, small colony enlarged, the continuous line showing the limit of the mucilage-envelope; cells show pseudo-vacuoles and cell-sheaths.

*Oscillatoria agardhii* Gom. forma (Fig. 4, A). Trichomes free-floating, solitary, straight throughout, seldom exceeding  $100\ \mu$  in length, tapering slightly at one end which is capitate. Cells  $3.5\text{--}4\ \mu$  broad,  $1\text{--}3\ \mu$  long, not constricted at the septa, with large pseudo-vacuoles.

This form differs from the type in the fact that the septa are not granular; in this respect, as well as in the form of the end of the trichome and the flat cells, it resembles *O. Martini* Frémy. The determination may require modification after examination of fresh material.

*Oscillatoria limnetica* Lemm. forma (Fig. 4, B). Trichomes solitary, straight or slightly curved, seldom more than  $100\ \mu$  long, not tapering towards the apex. End-cell bluntly rounded and without a calyptra. Cells  $1\ \mu$  broad,  $2.5\text{--}7\ \mu$  long, not constricted at the septa which are clearly visible, but devoid of granules.

The Ceylon form, though narrower, resembles the type in the proportion of cell-length to cell-breadth, but differs in the absence of constriction at the septa. PRESCOTT (1951) records material in which there was no constriction.

*Oscillatoria* sp. (Fig. 4, C). Trichomes free-floating, solitary, straight or curved, less than  $100\ \mu$  long, not constricted at the septa and not tapering at the ends, end-cell rounded. Cells cylindrical,  $0.3\ \mu$  or less broad,  $1\ \mu$  long; cell-wall very distinct. Examination of fresh material may make an exact determination possible.

*Lyngbya limnetica* Lemm. formae (Fig. 4, D). Filaments free-floating, solitary, straight or slightly curved. Trichomes  $0.7\text{--}1.0\ \mu$  broad, not constricted at the septa, not tapering at the ends, end-cell rounded, not capitate. Sheath firm, very thin, colourless. Cells cylindrical,  $2\text{--}3.5\ \mu$  long.

In the Ceylon material there appear to be two forms, one (Fig. 4, D, a) with thin septa as in the type, and the other (Fig. 4, D, b) with thick, hyaline septa. The first form is very similar to Lemmermann's *L. limnetica*, though the filaments are slightly narrower. The second form seems also to belong to this cosmopolitan species.

*Lyngbya* sp.? A (Fig. 4, E). Filaments free-floating, solitary, straight or slightly curved, seldom more than  $100\ \mu$  long. Trichomes,  $0.4\text{--}0.6\ \mu$  broad, not tapering at the ends, with a prominent granule on either side of the septa which are not constricted and difficult to detect, end-cell rounded. Sheath sometimes absent, firm, very thin, colourless. Cells cylindrical,  $3\text{--}6\ \mu$  long.

*Lyngbya* sp.? B (Fig. 4, F). Filaments free-floating, solitary, straight or curved, seldom more than  $100\ \mu$  long. Trichome interrupted at frequent intervals and consisting of short pieces,  $2\text{--}10\ \mu$  long. Neither sheath nor cross-walls visible. Diam. trich.  $0.1\text{--}0.2\ \mu$ .

Both this and the last may be filaments of *Phormidium*.

*Cylindrospermum* sp. (Fig. 4, G). Trichomes straight, less than  $60\ \mu$  long, solitary, free-floating. Heterocysts at one end only, elongate, conical, as broad as the vegetative cells. Cells cylindrical with rounded ends,  $1\text{--}1.5\ \mu$  broad,  $4\text{--}10\ \mu$  long, containing granules and pseudo-vacuoles.

In the absence of akinetes an exact determination is impossible.



*Raphidiopsis curvata* F. E. Fritsch forma (Fig. 4, H—J). The Ceylon form is narrower (diam.  $2\ \mu$ ) and the cells are generally longer ( $4\text{--}10\ \mu$ ) in proportion to their diameter. Cell-contents usually homogeneous, occasionally with pseudovacuoles.

*Raphidiopsis* sp. (Fig. 4, L—N). Trichomes mostly straight, solitary, free-floating, seldom exceeding  $120\ \mu$  in length, with both ends terminating in a point or frequently with one end rounded, generally

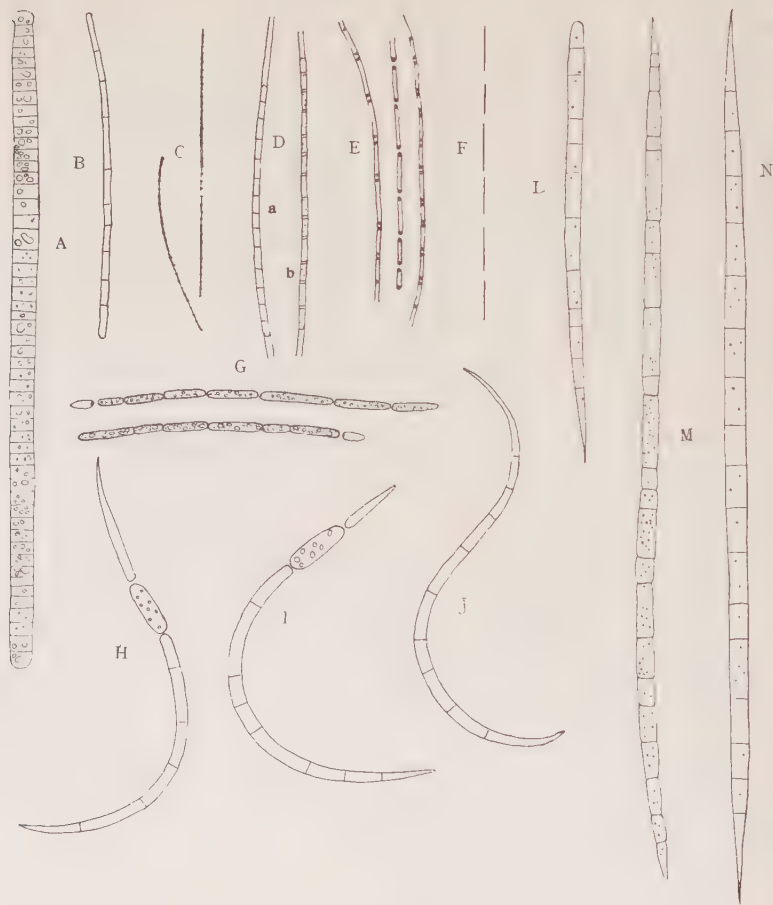


Fig. 4.

A, *Oscillatoria agardhii* Gom. forma. B, *O. limnetica* Lemm. forma. C, *Oscillatoria* sp., two trichomes. D, *Lyngbya limnetica* Lemm.; a, forma a; b, forma b. E, *Lyngbya* sp. A, three trichomes. F, *Lyngbya* sp. B. G, *Cylin-drospermum* sp. H—J, *Raphidiopsis curvata* F. E. Fritsch, forma. L—N, *Raphidiopsis* sp.

scarcely constricted at the septa although occasional trichomes show marked constriction. Cells in the widest part 3—3.2  $\mu$  broad, always longer than broad, with or without pseudovacuaes and granules. No mucilage-sheath could be detected even after staining.

This species resembles *R. mediterranea* Skuja, but in the absence of akinetes an exact determination is impossible.

### *Chlorophyceae*

*Staurostrum brachioprominens* Boerg. forma (Fig. 5, A, B). Cells small, excluding the processes about 1½ times longer than broad, deeply constricted, sinus acute-angled widening outwards; semicells biradiate campanulate, becoming wider towards the apex, lower angles broadly rounded, lower and upper lateral margins with short, delicate spines, upper angles produced into long, slightly tapering, diverging processes, tipped with three spines (up to 2  $\mu$  long) and bearing two irregular series of spines on their upper and lower margins and similar spines irregularly scattered over the rest of their surface. Chloroplast axile with a central pyrenoid and lobes extending into each angle. Length, without processes 12—16  $\mu$ , with processes 35—50  $\mu$ ; breadth, without processes 10—12  $\mu$ , with processes 50—60  $\mu$ ; breadth of isthmus approximately 4  $\mu$ .

The Ceylon form differs from the type mainly in the much narrower isthmus. It resembles *S. urinator* G. M. Smith (1) in the campanulate semicells with the lower lateral margins semi-circular and generally bearing an erect spine in the median portion; (2) in the production of the angles into long, slightly attenuated divergent processes terminating in three short spines; (3) in the presence on the upper and lower margins of the processes of conspicuous teeth directed away from the body of the semicell, the median area of the processes being smooth, but it differs, in its much smaller size and in the broadly oval vertical view of the body.

*Staurostrum coarctatum* Bréb. var. *subcurtum* Nordst. forma (Fig. 5, E—M). Cells small, as long as broad or a little longer, rather deeply constricted, sinus wide open acute-angled or sometimes rectangular; semicells obversely elliptic. Vertical view triangular with broadly rounded angles and slightly concave or convex sides; wall smooth. Chloroplast axile with one pyrenoid in each semicell. Length 15—20  $\mu$ ; breadth 12—20  $\mu$ ; breadth of isthmus 7—8  $\mu$ .

The Ceylon form differs in the form of the sinus.

*Staurostrum dejectum* Bréb. var. *patens* Nordst. forma (Fig. 5, C, D). Cells small excluding the spines about as long as or slightly longer



than broad, deeply constricted, sinus acute and widening outwards; semicells obversely elliptical, dorsal margin slightly, ventral margin strongly convex, upper angles rounded and produced into a short spine which projects obliquely outwards; wall smooth. Vertical view triangular, lateral margins slightly concave, angles broadly rounded and produced into a short spine. Chloroplast axile with one pyrenoid in each semicell. Length without spines, 18—20  $\mu$ ; breadth without spines, 16—20  $\mu$ ; breadth of isthmus 5—6  $\mu$ ; length of spine 4—5  $\mu$ .

The Ceylon form differs in size and shape.

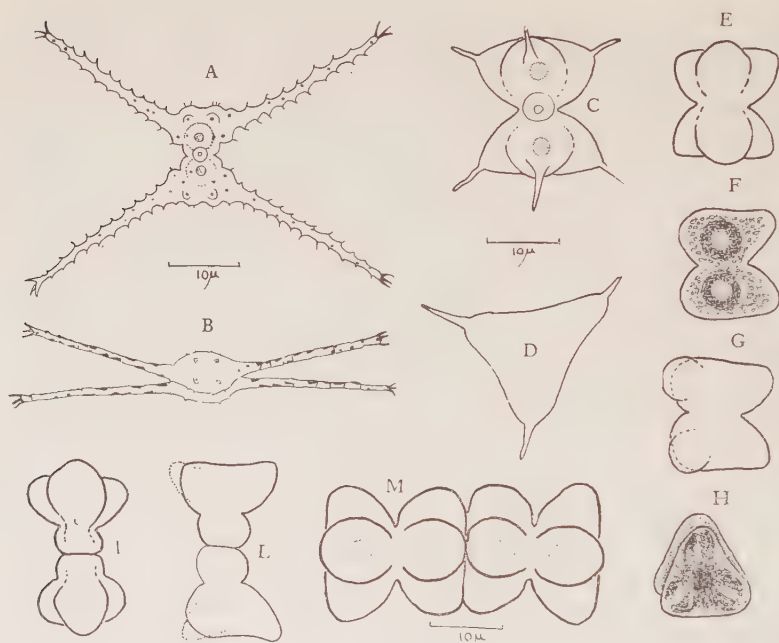


Fig. 5.

A, B, *Staurastrum brachioprominens* Boerg. forma; B, oblique vertical view. C, D, *S. dejectum* Bréb. var. *patens* Nordst. forma; C, front; D, vertical view. E—M, *S. coarctatum* Bréb., var. *subcurtum* Nordst. forma; E—G, three front-views; H, end-view; I, L, front-views of dividing cells; M, completed division.

### Bacillariophyceae

*Cyclotella ceylonica* sp. nov. (Fig. 6, A—J). Frustula a latere visa oblonga. Valvae circulares, diam. 5—25  $\mu$ , margine lata costis lanceolatis validis radiatis, 7—11 in 10  $\mu$  ornata. Pars centralis valvae paullo depressa et undulata; ad sinum juba excentrica posita est. Costae

marginales instar striarum delicatarum per partem centralem valvae, quae punctis magnis paucis ornata est, producuntur.

The distinctive feature of this species is the slightly depressed central area, into which the bluntly pointed tips of the marginal ribs dip (Fig. 6, D). Except in a few small cells (Fig. 6, J), the central area is undulate, partly convex and partly concave (Fig. 6, D, H). The two halves are separated by a ridge which is slightly excentric, with the two sides sloping unequally; that facing the convex half of the central area is short and slopes only little, while that facing the concave half is longer and slopes rather steeply. At the base of the ridge there are 1—6 coarse punctae; 1—3 larger punctae are present approximately midway between the ridge and the rim, being found more often on the convex portion of the central area. Between the pointed ends of the ribs and the ridge are rows of very fine punctae. Occasionally two, more rarely three, of these centripetal rows of punctae unite before reaching the ridge. The cells contain about eight large parietal discoid chromatophores.

In the arrangement of the marginal ribs *C. ceylonica* resembles *C. Meneghiniana* Kütz. var. *laevissima* (van Goor) Hust., but it differs in the ribs being lanceolate rather than cuneiform, with 7—11 ribs in  $10\ \mu$ ; in the presence of a central ridge; in the rows of fine punctae starting at the tips of the ribs and terminating at the ridge; and in the coarse punctae at the base of the latter and approximately midway between it and the rim.

This is the first record of a species of *Cyclotella* in the lowland freshwaters of Ceylon.

*Melosira ambigua* (Grun.) O. Müll. (Fig. 6 K, L). This was the dominant alga in the plankton of Lake Gregory during the period of investigation. The frustules varied from  $3.7$  to  $12\ \mu$  in width. The narrower and more elongate ones have the form of moderately curved filaments, and the length of the valve-jacket (FRITSCH, 1935, p. 566; „Höhe” of HUSTEDT) may be as much as 2.5 times the diameter; the number of punctae is 14—22 in  $10\ \mu$ . The wide filaments are more or less straight, the diameter varying from  $9$ — $12\ \mu$  and being equal to or greater than the length of the valve-jacket which varies from  $5.5$  to  $9\ \mu$ ; punctae 14—18 in  $10\ \mu$ . The chromatophore is usually single and parietal, extending from end to end of the frustule (Fig. 6, K, L); less often there are a number of small, round discoid chromatophores.

This species differs from *M. Roseana* Rabh. and *M. granulata* (Ehr.) Ralfs in the form of the sulcus, and from the latter also in the absence of spines. Lemmermann (1907) found considerable quantities of *M. granulata* var. *jonensis* f. *procera* Grun. and *M. granulata* var. *reticulata* O. Müll. in Lake Gregory, but no filaments of *M. granulata* were met with in this lake during the present investigation.

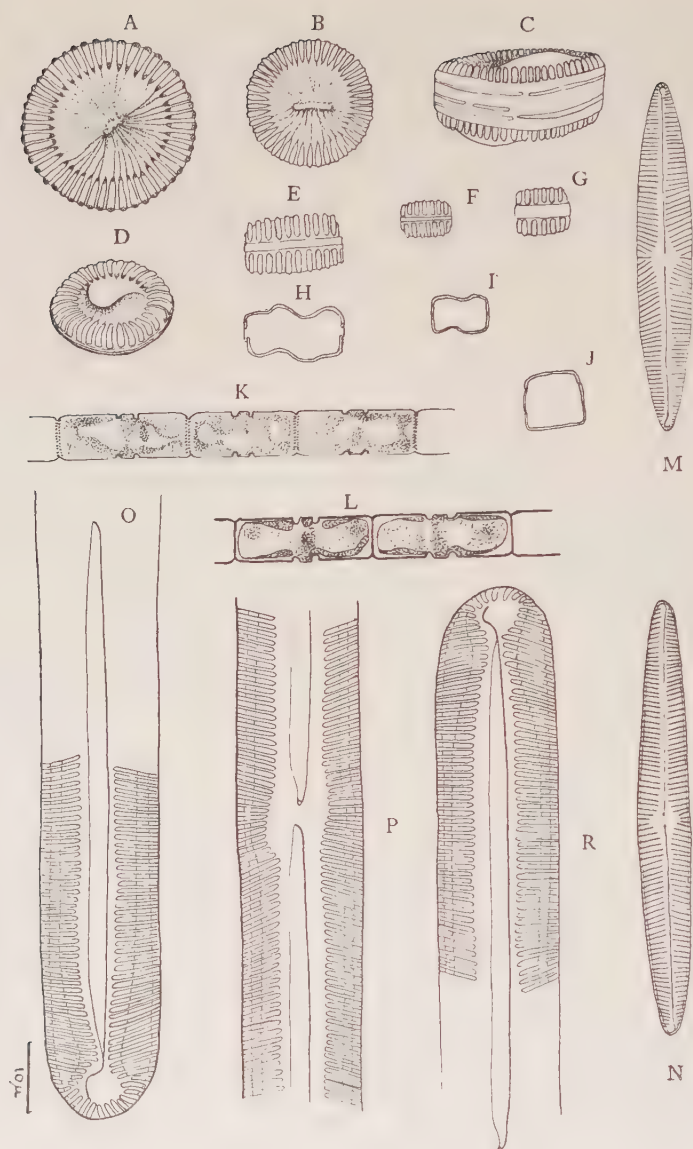


Fig. 6.

A—J, *Cyclotella ceylonica* sp. nov.; A, B, valve-views; C, E—J, girdle-views; D, oblique-view. K, L, *Melosira ambigua* (Grun.) O. Müll., cells with single parietal chromatophore. M, *Navicula cincta* (Ehr.) Kütz., f. *major* n.f. N, *N. radiosa* Kütz. forma. O—R, *Pinnularia tropica* Hust. forma.



*Melosira granulata* (Ehr.) Ralfs. This was constantly present in Nuwara Wewa tank, but never became dominant. It was represented by two varieties, viz. var. *angustissima* Müll., with filaments composed of long, narrow frustules ( $2\ \mu$  wide and about four times as long) in which the valve-jacket is several times longer than the diameter; and var. *muzzanensis* Meister, with frustules approximately  $15\ \mu$  wide and the length of the valve-jacket about half- to one-third the diameter. In my material both sulcus and pseudo-sulcus were as prominent as in the moderately narrow forms. There were about 10 punctae in  $10\ \mu$ .

*Navicula cincta* (Ehr.) Kütz. forma *major* f. nov. (Fig. 6, M). Cells fusiform, with bluntly rounded ends.  $40\text{--}50\ \mu$  long,  $7\text{--}8\ \mu$  broad; axial area narrow central area rhomboidal; striae clearly visible, 14 in  $10\ \mu$ , radial, shorter near the central area, parallel and more closely arranged (16 in  $10\ \mu$ ) towards the poles.

This form differs in being longer and broader.

*Navicula radiosa* Kütz. forma (Fig. 6, N). Cells  $50\text{--}90\ \mu$  long,  $7\text{--}12\ \mu$  broad; axial area narrow, central area small and rhomboidal; striae radial near the central area,  $12\text{--}13$  in  $10\ \mu$ , but convergent and closer ( $15\text{--}17$  in  $10\ \mu$ ) towards the poles.

This form differs in being narrower with more closely arranged striae.

*Pinnularia tropica* Hust. forma (Fig. 6, O—R). Frustules  $190\text{--}225\ \mu$  long,  $14\text{--}18.5\ \mu$  broad; raphe straight and simple, the branches curving to the same side at the central and polar nodules; axial area about one-third the width of the valve, but narrowing down considerably towards the poles. Costae  $9\text{--}10$  in  $10\ \mu$ , radial around the central nodule, parallel in the middle of the valve and convergent at the poles.

This form is longer and narrower than the species described by HUSTEDT from the Belgian Congo. It also differs in the more strictly linear valves and in the presence of much broader fenestrae near the poles (Fig. 6, O, R).

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# The distribution and periodicity of the phytoplankton of three Ceylon lakes\*

by

E. C. T. HOLSINGER

(with three figures in the text)

## INTRODUCTION

In the paper (HOLSINGER 1954) containing taxonomic notes on the plankton algae of these lakes, brief reference was made to differences in specific composition. The present account deals with the quantity and the periodic changes in the volume of the phytoplankton, as well as with the distribution of the major groups and of certain genera and species of algae.

The general characters of the lakes and their habitat conditions will first be considered, as well as the problems arising from the differences in specific composition and changes in the volume of phytoplankton during the year. Subsequently these problems will be discussed in relation to the Low Country and the Mountain lakes.

*Collection of the Samples.* Between March 1949 and March 1950 eight samples were collected from Beira Lake, six from Nuwara Wewa Tank and six from Lake Gregory, while between March 1951 and January 1952 MR. H. VERE CLAASZ collected seventeen further samples from Beira Lake. The samples were taken approximately in the middle of the larger section of Beira Lake, in the deepest part of Nuwara Wewa Tank about 200 m from the shore, and at a point about 500 m from the exit of the river from Lake Gregory, where the water flows continuously.

At each collection two samples of water were taken, one at the surface using a wide-mouthed jar, and the other at a depth of 180 cms. Immediately after collection the sample was agitated by forcing air into it and 15 ml samples were transferred to specimen tubes containing 15 ml of 8% formalin in distilled water, these smaller samples serving for quantitative work.

\*) Part of thesis (Ceylonese Plankton Algae) approved for the Degree of Doctor of Philosophy in the University of London and lodged in the Library of that University.



*Quantitative Estimation of Algal Growth.* After sedimentation with a saturated solution of iodine in potassium iodide, the algae of Beira Lake and Lake Gregory were estimated with an inverted microscope according to the UTERMÖHL—LUND technique (UTERMÖHL 1931; LUND 1949) but a different method was adopted in the case of Nuwara Wewa Tank, where approximately 50% of the phytoplankton consisted of very fine filaments, most less than  $1\ \mu$  broad, which could be counted more easily with a binocular microscope. The counting chamber consisted of a vulcanite ring, 20 mm internal diameter and 0.9 mm high, sealed to a glass slide by means of polystyrene-dibutylphthalate cement (LUND, 1949). A drop of a saturated iodine solution was placed in the chamber and 0.5 ml of the sample was then transferred to it with a pipette. After being left to stand for three or more hours, a fine circular cover-glass (2.5 cms diam.) was slid across the ring in such a way that no air bubbles were included. The counting was done under low power, except when a higher power was necessary to identify the organisms. With both techniques the whole of the base of the counting chamber was examined. Whenever necessary the sample was suitably diluted.

In order to obtain quantitative estimates of the total algal productivity in the three lakes and the quantities of individual species present various methods were followed. Since the phytoplankton consisted of unicellular organisms of diverse sizes and shapes, colonies varying greatly in number of constituent cells, and filaments differing in diameter and shape, it was decided, for the sake of uniformity, to express the approximate quantity of each species present in 1 ml of lake water in terms of its volume in cubic microns. Unicellular forms were estimated by counting and multiplying the total by the average volume of a single individual. The length of each filament of *Oscillatoria* and *Lyngbya* was measured in units of  $100\ \mu$  with the aid of a micrometer, and the total length multiplied by the mean cross-sectional area of the filaments. This was not easy to calculate accurately in *Melosira ambigua* and *M. granulata* owing to the great variability in diameter. In *Arthrospira platensis*, which varied little in diameter of trichome, length of cell and shape of spiral, the number of turns in each spiral was counted and the total multiplied by the average volume of a single turn. To estimate the volume occupied by the colonies of *Microcystis* spp., the areas of the individual colonies resting on the base of the counting chamber were determined and the sum multiplied by a conversion factor, usually calculated as an average by counting the number of cells in several squashed colonies of known area, but of varying size, to allow for the varying degree of crowding of the cells.

The estimates of algal volumes in the different lakes at the times

of sampling, expressed in cubic microns per ml, are tabulated in the thesis (cited in the footnote on p. 1).

*The General Characters of the Lakes.* These are summarised in the following Table:

	BEIRA LAKE (Colombo)	NUWARA WEWA TANK (Anuradhapura)	LAKE GREGORY (Nuwara Eliya)
Elevation above sea-level	1.8 m	90 m	1900 m
Area	83 hectares	932 h.	47 h.
Situation	Within a dense- ly populated city	In a vast uncultivated area covered with jungle	Near a small town and surrounded by hills, with tea-plantations
Soil	Sandy, lateritic, leached, acidic.	Loam, alkaline, high exchange- able basecontent	Peat-like surface; Replaceable basecontent low
State of water	Stagnant, two rainy seasons	Stagnant, one rainy season	Continuous flow
Temperature			
Mean annual	27° C	27° C	15 C
Highest record	33° C	36 C	24 C
Lowest record	17° C	13 C	— 0.6 C
Rainfall			
For 1949	218 cms	116 cms	187 cms
Highest on one day	21 cms	9.4 cms	6.3 cms
Cloud, av. mean amount	5.6	5.5	6.1
pH	8.1	8.2	7.3
Oxygen saturation			
At surface	65—190‰	80—170‰	85—150‰
At 180 cms	120‰	65—160‰	80—160‰
Ammonia (mgs per litre)			
Free	0.22—0.3	0.28—0.34	0.02—0.06
Albuminoid	0.78—0.88	0.36—0.53	0.14—0.56
Conductivity	1300 units	150 units	30 units
Phytoplankton			
Proportionate	productivity 100	40	70
Composition	Myxophyceae 95‰ Diatoms &c. 5‰	Myxophyceae 87% <i>Melosira</i> <i>granulata</i> 12% Chlorococcales &c. 1%	<i>Melosira</i> <i>ambigua</i> 65% Myxophyceae 30% Desmids, Chrysophyceae and Chlorococcales 5%

The two lowland waters are typically tropical and very different from Lake Gregory situated in the mountains. Fritsch (1907) says of the last “almost temperate, although on hot sunny days the water probably becomes rather warmer than it ever does in our parts”.

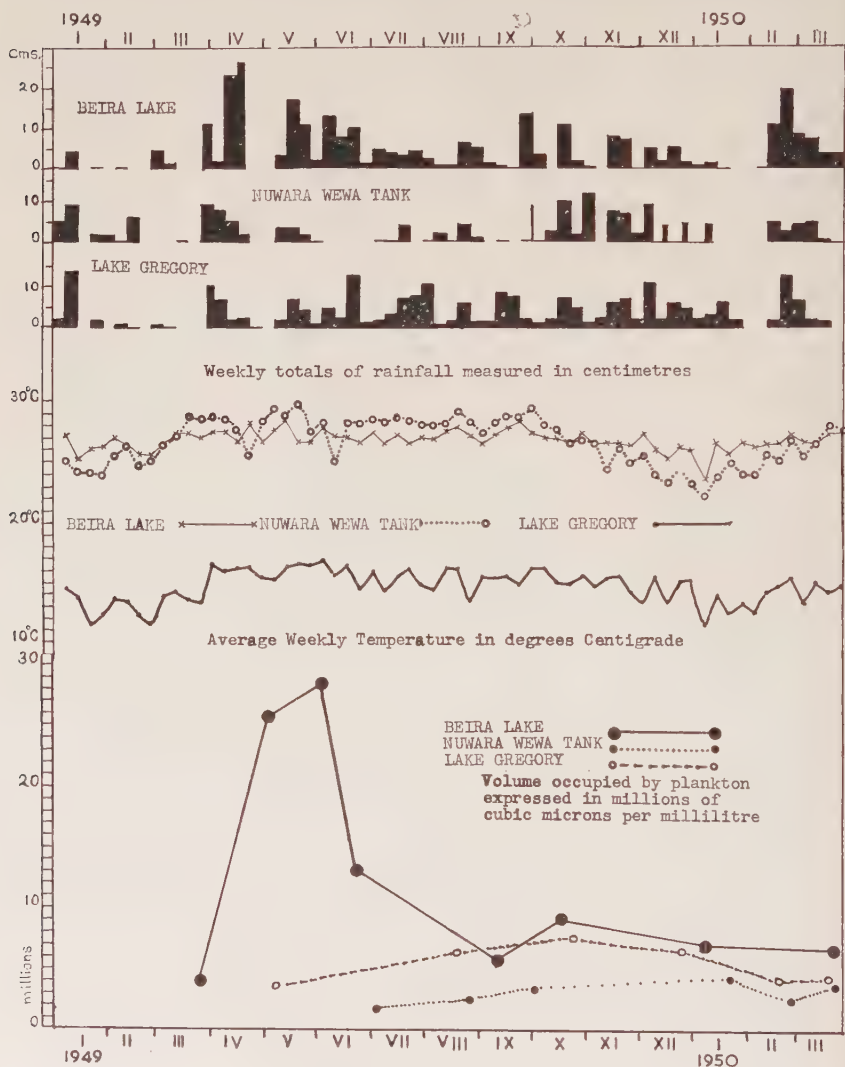


Fig. 1.

Weekly totals of rainfall in centimetres, average weekly temperature in degrees Centigrade, volumes of phytoplankton in millions of cubic microns per millilitre for Beira Lake (Colombo), Nuwara Wewa tank (Anuradhapura) and Lake Gregory (Nuwara Eliya), Jan. 1949—March 1950.



It also differs from the Low Country lakes in the lesser exposure to intense sunlight, owing to the greater amount of cloud, as well as the lower ammonia-content and a pH very near to neutral. These differences are reflected in the composition of the plankton, both Beira Lake and Nuwara Wewa Tank being dominated by Myxophyceae, while the plankton of Lake Gregory consists predominantly of Diatoms.

As regards algal productivity (Fig. 1), if that of Beira Lake is taken as 100, that of Lake Gregory and Nuwara Wewa Tank would be represented by 70 and 40 respectively. The high productivity of the first can be correlated with the high conductivity of its water (1300 units) equivalent to 104 parts per 100,000 total solids. The conductivity of the water of Lake Gregory, which is nearly twice as productive as Nuwara Wewa Tank, is, however, only 30 units as against 150 units for the latter. Although comparison of the two lakes is complicated by their situation in different climatic zones, the difference in productivity is probably due to the flow of water through Lake Gregory brought about by the river which enters at the north-west and passes out on the south-west side. This river traverses a densely populated part of Nuwara Eliya, as well as grassland on which cows graze, while its tributaries drain land on which tea is cultivated.

The high conductivity in Beira Lake is due to considerable organic pollution, the lake being bounded on two sides by slums from which rainwater drains extend into the lake. The high degree of pollution has existed for many years and in 1924 RAE published analyses which agree closely with those I have obtained. Large and sudden increases in pollution occur periodically during heavy rains (cf. below).

The low productivity of Nuwara Wewa Tank, is undoubtedly related to the low conductivity of the water due chiefly to the absence of any considerable organic pollution.

*Factors determining the character of the Algal Flora in the Low Country Lakes.* The dominance of Myxophyceae in these lakes is in agreement with what is known as to their nutrition. PEARSALL (1922, 1932), gave facts in support of the view that presence of nitrogenous organic matter is one of factors determining Myxophycean maxima in the English lakes. Recently GERLOFF, FITZGERALD, and SKOOG (1952), working with pure cultures in inorganic nutrient solutions, found that *Microcystis aeruginosa* has a very high nitrogen-requirement, attaining a maximum growth in culture solutions with N/P ratios as high as 75/1.  $\text{NaNO}_2$ ,  $\text{NaNO}_3$ , and  $\text{NH}_4\text{Cl}$  were equally effective as sources of nitrogen. The cultures were maintained at a pH as high as 9 and 10, in order to get a maximum growth in a period

of ten days, but the authors express the opinion that in natural waters, where the period is longer, heavy growths of *M. aeruginosa* may be produced at pH 8. They refer to unpublished work of A. E. WILLIAMS, who established that *Microcystis* cannot fix atmospheric nitrogen, and conclude that nitrogen is the element most likely to become a limiting factor for the growth of this alga in natural waters.

Beira lake, which receives large quantities of organic nitrogen, is slightly alkaline, moderately warm and exposed to intense sunlight, thus seems to provide a habitat favourable for an abundant development of *Microcystis*. There is a general correlation between the periodic influx of organic material during seasons of heavy rainfall and increases in the volume of phytoplankton, although a closer examination of the graphs in Fig. 2A & B shows that this correlation is not a simple one. Other factors are the intensity of the rainfall, the quantity of organic residues available and their richness in nitrogen. The effectiveness of rain as a flushing agent depends, not only on its total volume, but also on its intensity; thus a thunderstorm will flush more material into the lake than a number of showers precipitating an equal volume of water. It is not possible to assess the quantities of organic matter collecting between periods of heavy rainfall, but some idea may be formed of the variation in relative richness in nitrogen of the residues. When the intervening period is consistently dry the organic matter will dry up quickly with little loss of nitrogen, but when the residues are moistened by occasional showers, decomposition is hastened and there is considerable loss of nitrogen. Heavy rain, falling after a period of drought, therefore flushes into the lake residues richer in nitrogen than those introduced after a dry period interspersed with light showers.

Fig. 2, B shows two maxima in total algal productivity, one in June and the other in October. Both are equally large, although the first is preceded by more rain than the second. Since the heavy rains in May followed a period with frequent showers, the organic residues flushed into the lake by them had probably suffered losses in nitrogen. It is also likely that the heavier showers swept some residues into the lake, and support for this is given by the increase in algal productivity following the rain in the latter part of March. On the other hand, the heavy rains in September and the first week of October were preceded by a period of almost completely dry weather, during which losses of nitrogen into the air would be minimal, and losses to the lake nil. This probably explains why, although the total rainfall during the second wet season was smaller, it was as effective in increasing the volume of the phytoplankton as that during the first wet season. The absence of a more marked correlation between rainfall and productivity in November in Fig. 2B, can be ascribed to the preceding period

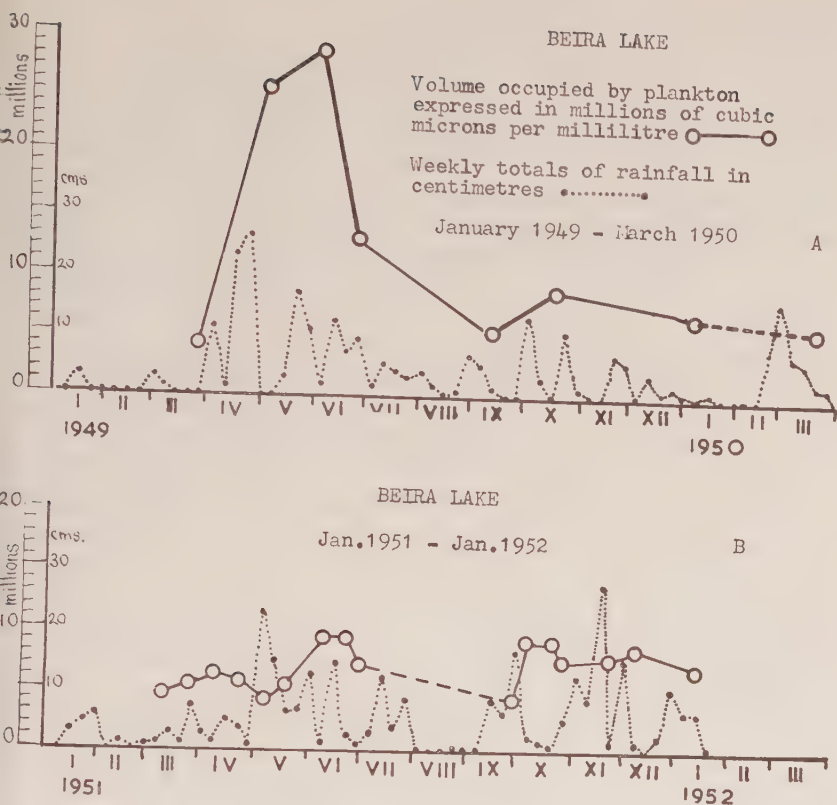


Fig. 2.

Volumes of phytoplankton in millions of cubic microns per millilitre and weekly totals of rainfall in centimetres for Beira Lake; A, Jan. 1949—March 1950; B, Jan. 1951—Jan. 1952.

being insufficient for the accumulation of organic residues. The correlation is actually between algal productivity and the nitrogen content of the water.

The annual rainfall (Fig. 1) in the Anuradhapura district surrounding Nuwara Wewa Tank is only a little more than half that at Colombo; moreover, the really heavy rainfall is limited to one season (October—November) and thunderstorms, precipitating large quantities of rain, are less frequent. These differences, together with the absence of organic accumulations near Nuwara Wewa tank, result in a much lower nitrogen-content than in Beira Lake at all times of the year. The graph does however show an increase in phytoplankton following the season of heaviest rainfall, thus supporting the view of a



general correlation between rainfall and algal productivity in these waters.

*The factors operating in the Mountain Lake.* As mentioned earlier the plankton of Lake Gregory differs from that of the Low Country lakes in the dominance of Diatoms, and from that of Nuwara Wewa Tank in its greater productivity. A comparison of the last and Beira Lake shows a positive correlation between productivity and conductivity, which does not obtain in the case of Lake Gregory where the inflowing river (cf. p. 5) will enrich it with organic matter derived from town and grassland and with nutritive salts leached by its tributaries from the cultivated hills around. Such accretions are comparatively small, but the constant supply introduced by the river is probably responsible for the higher algal productivity of Lake Gregory, as compared with that of Nuwara Wewa Tank.

It appears probable that the river also influences the specific composition of the phytoplankton of Lake Gregory. Since the soil drained by the river is derived from siliceous rocks, it may be supposed that the river maintains a supply of silicate adequate to the needs of its diatom-population. PEARSALL (1923, 1930, 1932) has stressed the importance of silica in the growth of Diatoms and provides evidence for the view that Diatom periodicity is largely conditioned by floods. The effect of floods on the growth of *Melosira ambigua* is clearly shown in Fig. 3. A sharp increase in the amount of this Diatom occurred between August and October 1949, following the season of heaviest rainfall between the middle of June and the end of July. Subsequently, the productivity gradually fell reaching its lowest level four weeks after the rains had virtually ceased.

Although Desmids form only a very small part of the plankton of Lake Gregory, their productivity is of interest. *Staurostrum brachiprominens* (Fig. 3), which was relatively abundant in May 1949, steadily diminished month by month and by December was an insignificant constituent of the plankton, but at this time *S. coarctatum* var. *subcurtum* and *S. dejectum* var. *patens* were rapidly increasing and attained a maximum growth by February 1950. The periods of greatest relative abundance of these Desmids occur in seasons of very little rain or no rain. In the case of *S. brachiprominens* there had been only 0.3 cms during the three weeks preceding sampling, while in that of *S. coarctatum* and *S. dejectum* there had been 0.77 cms during the preceding three weeks, all of which fell during the three days immediately preceding sampling. It is further of interest that in both instances the increase in Desmid productivity is correlated with a marked decrease both of *Melosira ambigua* and of species of Myxophyceae.

# LAKE GREGORY

Volume occupied by total plankton expressed in millions of cubic microns per millilitre ○—○

Weekly totals of rainfall measured in centimetres .....●.....

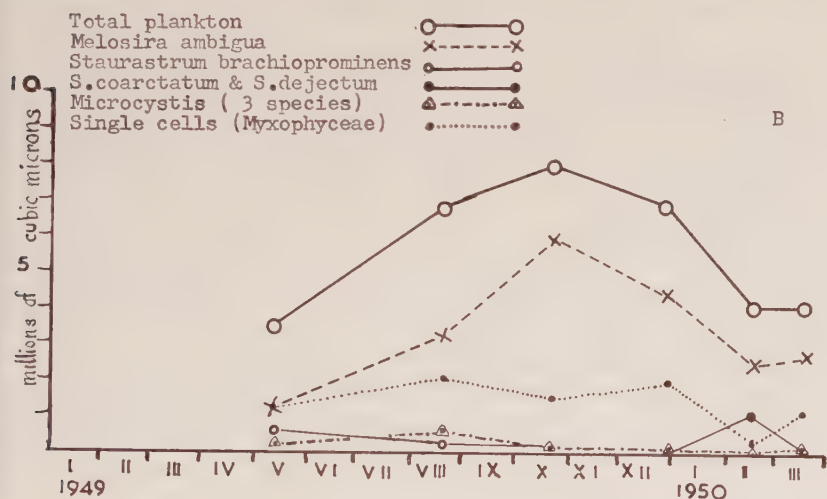
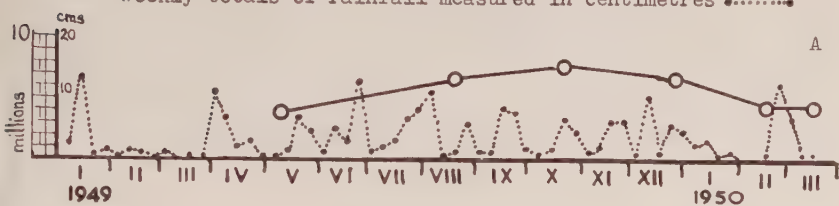


Fig. 3.

Lake Gregory, May 1949—March 1950. A, volumes of phytoplankton in millions of cubic microns per millilitre and weekly totals of rainfall in centimetres; B, volumes of total phytoplankton and volumes of the commoner species expressed in millions of cubic microns.

"Single cells (*Myxophyceae*)", in the legend, refers to an assemblage of species of *Myxophyceae* which occurred as unicells and very small colonies the constituent cells of which were counted separately. These cells which had numerous pseudovacuoles and were 3—5  $\mu$  in diam. were present in all three lakes.

The periodicity of the species of *Staurastrum* in Lake Gregory can be explained on the basis of certain conclusions arrived at by PEAR-SALL (1932) and others. For the English lakes PEAR-SALL concluded that "in general, a low N/P ratio and a low calcium content are likely to favour desmids". It is reasonable to assume a deficiency of calcium

in a lake, with a pH very near the neutral and situated in a region in which the underlying rock is a gneiss and the soil is strongly leached of nutritive ions. It appears very probable that during dry periods the content both of nitrogen and of calcium diminishes in Lake Gregory. At such times introduction of fresh supplies of these elements would be greatly reduced, and conditions would not be favourable for the growth of species requiring more abundant supplies of them. It appears probable that Desmids increase in numbers when conditions are such that other algae cannot swamp them.

## SUMMARY

The phytoplankton of three Ceylon lakes, two situated in the warm lowlands and one in the cool mountains has been investigated. Certain similarities and differences in regard to growth, distribution and periodicity of the plankton algae are discussed and related to environmental conditions.

The lowland lakes are dominated by Myxophyceae which form 95% and 87% of the phytoplankton respectively, while in the mountain lake, which is temperate rather than tropical, Diatoms form 65% of the phytoplankton. Of the lowland lakes that in the centre of the densely populated city of Colombo has an algal productivity which is two and a half times as great as that situated in a vast area of uncultivated land. The mountain lake, surrounded by cultivated hills, occupies an intermediate position between the low country lakes in regard to productivity.

The environmental factors mainly affecting algal growth, distribution and periodicity in these lakes are temperature, rainfall, sunshine, movement of the water, amount of influx of organic matter and nature of the surrounding soil. In assessing the effect of rainfall consideration has been given not only to the total precipitation, but also to its intensity and the occurrence of periods of drought between those of heavy rainfall.

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The writer is indebted to Prof. W. H. Pearsall, under whose direction this investigation was undertaken, for advice and encouragement, to Prof. F. E. Fritsch for guidance at various stages of the work and to the Director of the Ceylon Department of Meteorology for rainfall and temperature data.



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Aus dem wissenschaftl. Labor der Membranfiltergesellschaft  
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# Hydrobakteriologische Untersuchungen der Fulda unter Anwendung der Membranfiltermethode

von

ADELAIDE BELING und HOLGER W. JANNASCH

Herrn Prof. Dr. A. Thienemann zum 70. Geburtstag gewidmet.

Unter den Lebewesen, die den Stoffhaushalt eines Gewässers bestimmen, spielen die kleinsten Organismen, die Bakterien, eine wesentliche Rolle. Durch die mannigfachen Möglichkeiten dieser Organismen, chemische Prozesse energetisch auszunutzen, wird die Mineralisation der organischen Reststoffe zu dem Fundament, auf dem das Leben der höheren Tiere und Pflanzen basiert. Obwohl die Bedeutung dieser Tatsache in der Hydrobiologie bekannt ist, hat man sich bisher mit der eigentlichen Erforschung dieser komplizierten Verhältnisse noch kaum befassen können. Die Gründe dafür liegen besonders in einer unzureichenden Untersuchungsmethodik.

Es muß zunächst eine Möglichkeit bestehen, die Dichte und die Formen der Bakterien im Wasser zu bestimmen, ähnlich wie es bei der Untersuchung des Zoo- und Phytoplanktons schon seit langem grundlegend durchgeführt wird. Aber selbst die feinsten Planktonnetze vermögen nicht, Bakterien aufzufangen, und keine Methode der Konzentrierung durch Sedimentation, Zentrifugation, Filtration etc. liefert bisher befriedigende Ergebnisse quantitativer Untersuchungen.

Um die Dichte der Bakterien in Gewässern zu bestimmen, bedient man sich allgemein der Plattenmethode nach KOCH, die für hygienische Untersuchungen genügen mag, jedoch für hydrobakteriologische Arbeiten unzureichend ist, da sie nur relative Ergebnisse bringen kann. Wasserbakterien werden auf Fleischteptonagar bzw. Gelatine gezüchtet und die gewachsenen Kolonien ausgezählt. Die Zahl der Kolonien gibt ein Bild der Verunreinigung des Wassers.

KOLKWITZ (1) stellte z.B. auf diese Weise fest, daß die ungefähre Zahl von 1.000.000 Keimen pro ccm ein polysaprobies, < 100.000 ein mesosaprobies und < 500 ein oligosaprobies Gewässer charakte-

riert. Bei Anwendung der Plattenmethode darf jedoch nicht vergessen werden, daß auf Fleischpeptonagar oder Gelatine nur bestimmte meist wasserfremde Bakterienarten sich zu entwickeln vermögen, während die übrigen wassereigenen auf diesen Nährböden nicht wachsen, verkümmern und demnach nicht als Kolonien erscheinen können. Aus dieser Erkenntnis heraus ist die Plattenmethode bereits öfters diskutiert worden, und man suchte neue Wege zur Erfassung sämtlicher Bakterien.

Im Jahre 1928 schlug CHOLODNY (2) eine neue Methode zur quantitativen Bestimmung des Bakterienplanktons vor. Er legte seiner Neuerung eine Methode zu Grunde, die KOLKWITZ (3) bereits 1924 für die quantitative Bestimmung des Zooplanktons anwandte.

Er konzentrierte die Organismen durch Filtration auf der Oberfläche eines Membranfilters mit der Porenweite von  $2-3\ \mu$ . In den letzten Jahren wandte u.a. W. SCHMITZ (4) Cellafilter, grob, für Phytoplankton-Untersuchungen mit gutem Erfolg an.

CHOLODNY benutzte Membranfilter feinerer Porengröße ( $1-1,5\ \mu$ ). Er war der Meinung, daß diese Porenweite für die meisten Bakterien ausreichen würde. Er filtrierte 100 ccm Flußwasser, das nach der Entnahme sofort mit  $3-5\%$  igem Formalin fixiert wurde, im Kolkwitzapparat durch den Membranfilter bis auf einen Rest von  $4-5\ \text{ccm}$  ab, der dann in ein steriles Röhrchen gegossen wurde. Alle Bakterien, die in den 100 ccm Flußwasser enthalten waren, wurden so in diesem Rest konzentriert. Hiervon wurden wiederum 0,05 ccm entnommen, auf einen Objektträger gebracht, eine halbe Stunde lang mit  $3\%$  igem Erythrosin gefärbt, mikroskopiert und ausgezählt. Für die Zählung benutzte CHOLODNY ein Okularnetzmikrometer, bei dem das kleinste nicht mehr unterteilte Quadrat die Größe von  $400\ \mu^2$  hatte. Größenteils wurden 100 Quadrate ausgezählt. Nach der Multiplikation erhielt CHOLODNY die Zahl der Bakterien in 1 ccm Wasser. Die Werte überstiegen die der Plattenmethode um das 50 bis 100-fache.

Dieses Ergebnis bestätigt die Annahme, daß ein großer Teil der Bakterien bei der Plattenmethode nicht erfaßt wird. Somit wäre die KOLKWITZ'sche Angabe über die Zahl der Keime, die charakteristisch für poly-meso- und oligosaprobe Gewässer sein soll, zu korrigieren. Die Direktmethode bringt wesentlich größere Keimzahlen.

BARSOFF (5) (später RASUMOV (6), DIANOVA-WOROSCHILOWA (7) u.a.) vereinfachte 1933 diese Filtrationsmethode wesentlich. Er färbte nunmehr die Bakterien direkt auf dem Filter auf folgende Weise:

Das Filter wurde nach der Filtration mit  $3\%$  igem Formalin fixiert und auf  $2-3$  Papierfilterscheiben, die mit  $3\%$  iger Erythrosinlösung getränkt waren, gelegt. Innerhalb von  $4-6$  Stunden war die Färbung beendet. Danach wurde das gefärbte Filter wieder in den



Apparat eingespannt und mit vorfiltriertem, dest. Wasser entfärbt. Anschließend wurde es im Trockenschrank getrocknet, mit Cedernöl durchsichtig gemacht, und die Bakterien mikroskopisch gezählt. (Neue Lit. s. bei JANNASCH, 13.) Nach der Multiplikation erhielt BARSOFF annähernd die Keimzahlen, die seinerzeit CHOLODNY gefunden hatte.

Gleichzeitig versuchte BARSOFF die Züchtung der Bakterien direkt auf dem Filter. Er legte nach der Filtration die Filter mit dem Rückstand auf verschiedene Nährböden, wo sich durch Diffusion der Nährstoffe durch den Filter die Bakterien zu sichtbaren Kolonien entwickeln können. Mit dieser Methode ist es möglich, größere Wassermengen zu untersuchen und gleichzeitig unter Zuhilfenahme spezifischer Nährböden verschiedene physiologische Bakteriengruppen zu differenzieren.

Bisher richtete sich das Hauptaugenmerk der bakteriologischen Wasseruntersuchung auf die Bestimmung der Keimzahl, den Coli-nachweis und in einigen Fällen auf pathogene Keime.

Die kulturelle sowie die direkte Membranfilter-Methode ermöglicht eine Beobachtung physiologisch sowie morphologisch verschiedener Bakteriengruppen bei einer wesentlichen Zeit- und Materialersparnis.

1948 wurde diese Methode von uns während einer limnologischen Fuldauntersuchung mit gutem Erfolg angewandt. Die Filtration der Wasserproben erfolgte an Ort und Stelle. Ein Teil der Filter wurde sofort auf verschiedene Nährböden gelegt. Die restlichen Filter fixierten wir mit 3%igem Formalin und legten sie zur späteren direkten mikroskopischen Untersuchung in sterile Tüten. Die Ergebnisse dieser Fuldauntersuchung fanden im Jahresbericht der Limnologischen Station Freudenthal 1951 Erwähnung (8).

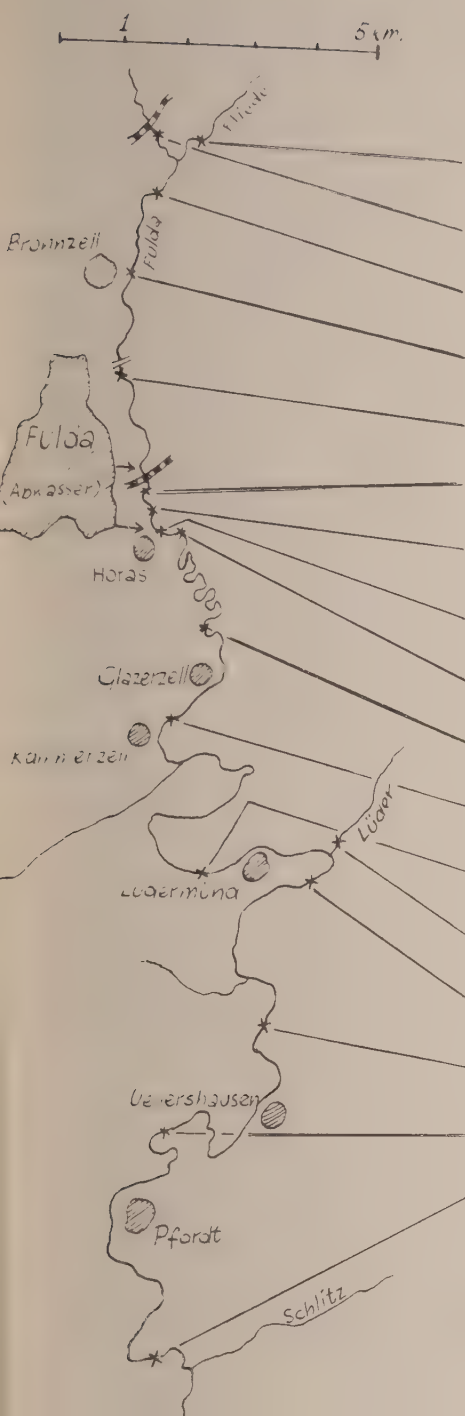
Nachstehend sind für verschiedene Flußabschnitte der Fulda die Durchschnittswerte der Keimzahl unter Anwendung der Platten- und der direkten Membranfilter-Methode angegeben.

Tabelle 1

	Keimzahl in 1,0 ccm	
	Plattenmeth.	Direkte Membranfilter-Methode
Oberlauf	535	30404
Obermittellauf	8533	227509
Untermittellauf	3128	173840
Unterlauf	325	18450

Erwähnt sei hier noch, daß bei der direkten Zählung auf dem Filter insofern Schwierigkeiten auftreten können, als sich die Bak-

Tabelle 2



Datum	Probe	Wasser- temp.	Chemische Untersuchung							Bakteriologische Untersuchung							
			pH	$O_2$	$O_2^*$	$NH_4/N$	$NO_2/N$	$NO_3/N$	$H_2S$	Keimzahl	Coli- kolon.	Pathog. Typhus	Keime Paratyph.	Direktmethode			
				mg/l	(750mm)									Stäbchen	Kokken	Vibr.	Spir.
2. 10. 1951	I	12,8	6,8	10,78	101,0	o	0,01	1,5	n.n.	3 300	60	+	n.n.	+++	+	++	++
	II	14,1	6,8	9,85	95,2	o	n.n.	0,9	n.n.	900	40	n.n.	n.n.	++	++	+	+
	III	14,7	6,8	9,20	90,0	0,08	n.n.	1,5	n.n.	7 000	70	+	n.n.	+++	++	++	++
	IV	14,7	6,8	8,71	85,1	0,05	0,02	1,9	n.n.	2 500	80	n.n.	n.n.	+++	++	++	++
	V	14,7	7,5	5,41	62,5	0,68	n.n.	0,8	0,17	22 000	o	+	n.n.	++++	++	++	++
	VI	14,8	-	4,10	40,0	1,33	0,15	1,3	0,50	o	4 000	n.n.	n.n.	++++	+	++	++
3. 10. 1951	VII	12,5	7,3	3,44	32,0	1,88	0,03	2,3	0,24	50 000	4 000	n.n.	n.n.	++++	+	++	++
	VIII	13,8	7,5	3,14	30,0	2,00	0,01	2,1	0,30	160 000	7 000	+	+	++++	+	++	++
	IX	13,6	7,3	3,40	35,5	1,89	0,01	2,5	0,10	33 000	8 500	+	n.n.	++++	+	++	++
	X	14,0	7,4	2,12	21,0	2,70	0,08	0,3	n.n.	84 000	22 800	n.n.	-	++++	+	++	++
	XI	14,0	7,3	2,20	21,8	1,25	0,03	0,5	n.n.	19 000	o	n.n.	n.n.	++++	+	++	++
	XII	14,6	7,3	4,50	43,9	0,82	0,04	0,8	n.n.	18 000	180	n.n.	n.D.	+++	++	++	+
4. 10. 1951	XIII	10,4	7,2	11,00	97,8	n.n.	n.n.	0,1	n.n.	800	10	n.n.	n.n.	++	+++	-	-
	XIV	10,1	7,1	o	o	0,30	0,01	2,1	n.n.	1 500	107	n.n.	n.n.	+++	++	+	+
	XV	10,1	6,9	o	o	0,11	0,01	0,8	n.n.	250	30	n.n.	n.n.	++	+++	-	-
	XVI	12,2	6,8	o	o	0,07	0,03	0,9	n.n.	110	6	n.n.	n.n.	+	++	-	-
	XVII	13,5	7,0	o	o	0,13	n.n.	1,4	n.n.	1 050	10	n.n.	n.n.	++	+++	+	-

n.n. = nicht nachgewiesen; o = ausgefallen; \* = Sättigung in %.





terien oft auf die Tiefe des Rückstandes verteilen. Eine Zählung in verschiedenen optischen Ebenen ist daher in diesen Fällen notwendig.

Bei der Zählung der Keime konnten wir beobachten, daß die einzelnen Wasserproben eine sehr unterschiedliche Zusammensetzung der morphologischen Formen aufwiesen. In einigen Proben dominierten große, dicke Stäbchen, Streptobazillen, Vibrionen, Spirillen und Fadenbakterien (Abb. 1). In anderen wiederum herrschten Kokken und sehr kleine Stäbchen vor stets mit einer viel geringeren Keimzahl verbunden (Abb. 2). Die gleiche Feststellung machte seinerzeit RADZIMOWSKI (9) bei verschiedenen Gewässeruntersuchungen mit Hilfe der Membranfilter-Methode nach CHOŁODNY.

Um dieser Erscheinung noch einmal nachzugehen, untersuchten wir im Herbst 1951 einen Flußabschnitt der Fulda. Wir wählten den Teil unterhalb der Stadt Fulda, bei dem die Abwasserzuleitung in keinem erträglichen Verhältnis zu der Gesamtwasserführung steht. Die starken Kontraste in der Abwasserführung des Flusses erwiesen sich für den Zweck unseres Vorhabens als besonders geeignet.

Bei dieser dreitägigen Untersuchungsfahrt wurden insgesamt 17 Wasserproben mit Hilfe der Plattenmethode und der kulturellen sowie direkten Membranfilter-Methode bearbeitet. Gleichzeitig erfolgte die Entnahme von Wasserproben für chemische Analysen, die von W. Schmitz, Flußstation Freudenthal, durchgeführt wurden. Die bakteriologischen Untersuchungen wurden an Ort und Stelle gemacht. Für diesen Zweck benutzten wir einen Expeditionskasten (Membranfiltergesellschaft Göttingen), der sämtliche Geräte und Hilfsmittel enthielt. Die für die Untersuchungen notwendigen Nährböden hatten wir vorher in unserem Laboratorium zubereitet.

Die entnommene Wasserprobe filtrierten wir im Coli-Apparat durch einen Membranfilter Co<sub>5</sub>. Vor der Filtration jeder weiteren Probe wurde der Filtrierapparat durch Abbrennen sterilisiert. Wegen fehlender Mittel mußten sich unsere Untersuchungen auf die Keimzahlbestimmung, den Nachweis von Bact. coli und pathogenen Keimen beschränken.

Von jeder Wasserprobe wurden verschiedene Mengen filtriert und zwar:

1. für die Keimzahlbestimmung m. Plattenmethode — 0,001 ccm u. 0,1 ccm.
2. für die Keimzahlbestimmung m. Direktmethode — 0,1 ccm u. 1,0 ccm.
3. für den Colinachweis auf Endoagar — 0,1 ccm, 1,0 ccm, 5 ccm.
4. für den Nachweis path. Bakterien (Wismutsulfitagar) — 1,0 ccm u. 5 ccm.

Nach der Filtration legten wir einen Teil der Filter auf die entsprechenden Nährböden (Fleischagar, Endoagar und Wismutsulfagar), während der andere Teil der Filter an der Spiritusflamme getrocknet und zur Verwendung für die Direktmethode in sterile Tüten eingelegt wurde. Da uns kein Formalin zur Verfügung stand, entfiel die Fixierung der Filter. Dieser Umstand sollte uns später auf eine interessante Erscheinung aufmerksam machen.

Nach unserer Rückkehr ins Labor (Hygienisches Institut Fulda) wurden die Petrischalen mit den aufgelegten Filtern in den Brutschrank gestellt. Nach 24—48 Stunden konnten die gewachsenen Kolonien gezählt und auf Schrägagar zur weiteren Prüfung der Stämme überimpft werden. Auf diese Weise konnten wir bei den Fuldauntersuchungen an mehreren Stellen Typhus und Paratyphus nachweisen. (Die biochemischen und serologischen Arbeiten wurden im Medizinaluntersuchungsamt Göttingen durchgeführt).

Bei dieser Gelegenheit möchten wir Herrn Dr. Krüpe, Hygienisches Institut Fulda, und Fräulein Schulz, Medizinaluntersuchungsamt Göttingen, unseren verbindlichsten Dank sagen.

Zur mikroskopischen Untersuchung der Filter, die wir in sterile Tüten eingelegt hatten, kamen wir erst nach einem halben Jahr. Wir färbten zunächst die Filter — wie bereits beschrieben — fertigten Präparate an und mikroskopierten. Dabei machten wir die Feststellung, daß die Bakterien nicht gefärbt waren, und entsannen uns, sie seinerzeit nicht fixiert zu haben. Die restlichen Filter wurden daraufhin 30 Minuten lang bei 60° im Trockenschrank fixiert und anschließend — nun mit gutem Erfolg — gefärbt. Allerdings machten wir dann die überraschende Feststellung, daß anstatt regelmäßig verteilter Bakterien bereits gut entwickelte Kolonien zu sehen waren. Die Bakterien hatten sich demnach ohne Nährboden vermehrt (Abb. 3—8). Offenbar genügten die auf dem Filter zurückgebliebenen Nährstoffe für das Wachstum der Bakterien. Diese Erscheinung nahm uns natürlich die Möglichkeit der direkten Keimzahlbestimmung. Die Daten für die Direktmethode in Tabelle 2 konnten daher nicht angegeben werden. Stattdessen vermochten wir die verschiedenen Bakterienformen gut zu beobachten.

Nachstehend sei hier eine kurze stichwortartige Beschreibung der Stellen wiedergegeben, an denen die Wasserproben entnommen wurden. Zugleich werden die bakteriologischen Ergebnisse genannt und neben der Charakterisierung des Bakterienplanktons gegebenenfalls der Verschmutzungszustand des Flußabschnittes erwähnt.

Die Kartenskizze soll einen Überblick über die Lage der Entnahmestellen zu den Nebenflußmündungen und den Abwasserzuflüssen geben.

*Probe I, 2.10.51, 11 Uhr 10*

Fliede bei Ziegel, 100 m vor der Mündung in die Fulda.

Breite: 20 m; Tiefe: 2 m; Strömungsgeschw.: 40 cm/sek.

Wassertemp.: 12,8°; pH. 6,8.

Ufer: Rechts steil, älterer Baumbestand mit Unterholz; links Wiese mit dichtem Uferbestand von Typha, Phragmites, Sparganium und Glyceria.

Untergrund: Sandig mit Ranunc. fluitans und Elodea can. überzogen.

Probenentnahme: Flußmitte, 1 m tief.

Ergebnisse: Keimzahl in 1,0 ccm — 3.300

Bakt. coli in 1,0 ccm — 60

pathog. Keime in 1,0 ccm — 2.

Überwiegend stäbchenförmige Bakterien, die an einigen Stellen des Filters zu Kolonien herangewachsen sind. Eine große Anzahl Vibrionen, Spirillen und Fadenbakterien, dagegen wenig Kokken. Größe der Stäbchen: ca. 2  $\mu$  bis 4,5  $\mu$ ;  $\phi$  1  $\mu$ ; Größe der Kokken: 1  $\mu$  bis 1,5  $\mu$ .

Trotz des hohen Sauerstoffgehaltes zeigt die Fliede eine relativ starke Verschmutzung. (Nitratgehalt 1,6 mg/l)

*Probe II, 2.10.51, 13 Uhr 50*

Nordarm der Fulda, Eisenbahnbrücke.

Breite: 2 m; Tiefe: 0,5 m; Strömungsgeschw. 50 cm/sek.

Wassertemp.: 14,1°; pH. 6,8.

Ufer: Überschwemmtes Wiesenland. Weidengesträuch.

Untergrund: Sandsteingeröll, teilweise mit Kieselalgen überzogen.

Probenentnahme: Rechtes Ufer, 20 cm tief.

Ergebnisse: Keimzahl in 1,0 ccm — 900

Bakt. coli in 1,0 ccm — 40

pathog. Keime in 1,0 ccm — nicht nachgewiesen.

Kleinere Stäbchen von dünner und langer Form; in fast gleicher

Menge Kokken. Einzelne Vibrionen, Spirillen und Fadenbakterien.

Größe der Stäbchen: 1,5—2,0  $\mu$ . Größe der Kokken 1—1,5  $\mu$ .

*Probe III, 2.10.51, 15 Uhr*

100 m unterhalb der Fliedemündung (Ausfluß der Badeanstalt oberhalb).

Breite: 8 m; Tiefe: 1 m; Strömungsgeschw. 20 cm/sek.

Wassertemp.: 14,7°; pH: 6,8.

Ufer: Steil, unterspült Erlenbestand in der Krautschicht Utricularia.

Untergrund: Lehmschlamm.

Probenentnahme: Linkes Ufer unter der Brücke 30 cm tief.



Ergebnisse: Keimzahl in 1,0 ccm — 7000  
Bakt. coli in 1,0 ccm — 70  
pathog. Keime in 5,0 ccm — 3 Kolonien.

Es dominieren stäbchenförmige kurze-dicke oder lange-dünne Formen mit und ohne Sporen. Vibrionen, Spirillen und Kokken reichlich vorhanden, dagegen keine Fadenbakterien. Auch hier hatten sich einzelne Kolonien auf dem Filter entwickelt. Größe der Stäbchen wie in Probe I.

Es ist anzunehmen daß die hohe Keimzahl sowie der Nachweis von pathogenen Bakterien auf den Einfluß des Fließwassers und der Badeanstalt zurückzuführen ist.

*Probe IV, 2.10.51, 16 Uhr 25*

Steinbrücke bei Bronnzell

Breite: 8 m; Tiefe: 50 cm; Strömungsgeschw. 10 cm/sek.

Wassertemp.: 14,7°; pH 6,8

Ufer: Beiderseitig steiler Wiesenabbruch.

Untergrund: Steinig, Elodeahorste.

Probenentnahme: Rechtes Ufer, 25 cm tief.

Ergebnisse: Keimzahl in 1,0 ccm — 2600

Bakt. coli in 1,0 ccm — 80

pathog. Keime in 1,0 ccm — nicht nachgewiesen.

Das Bakterienplankton zeigt etwa das gleiche Bild wie in Probe III. Dazu kommen eine geringe Anzahl Fadenbakterien und Diatomeen.

*Probe V, 2.10.51, 17 Uhr 5*

Alsfelder Brücke.

Breite: 40 m; Tiefe 1—2 m; Stauwasser.

Wassertemp. 14,7°; pH 7,5.

Ufer: Wiesen und Weideland, Sparganium und Urtica.

Untergrund: Verschlammte, Überzüge von Blaualgen.

Probeentnahme: Rechtes Ufer, 50 cm tief.

Ergebnisse: Keimzahl in 1,0 ccm — 22.000

Bakt. coli in 1,0 ccm — (ausgefallen)

pathog. Keime in 1,0 ccm — 3 Kolonien

Große Mengen verschiedener Stäbchen. Reiche Koloniebildung auf dem Filter. Die Anzahl der Kokken hat abgenommen. Vibrionen, Spirillen und Fadenbakterien sind reichlich vorhanden.

Der Fluß befindet sich hier bereits im Stadtgebiet von Fulda und zeigt eine deutliche Verunreinigung.

*Probe VI, 2.10.51, 17 Uhr 30*

Unterhalb der Eisenbahnbrücke (Industrieabwässer).

Breite: 6 m; Tiefe: 20 m; Strömungsgeschw. 50 cm/sek.

Wassertemp.: 14,8°; pH (fehlt).

Ufer: Wiese, Schutthalden mit Urtica-Bewuchs.

Untergrund: Steinig mit Grün- und Blaualgenüberzug.

Probenentnahme: Linkes Ufer, 15 cm tief.

Ergebnisse: Keimzahl in 1,0 ccm — (überwachsen)

Bakt. coli in 1,0 ccm — 80.000

pathog. Keime in 1,0 ccm — nicht nachgewiesen.

Fast nur stäbchenförmige Bakterien mit und ohne Sporen. Im übrigen Fadenbakterien, wenig Vibrionen und Spirillen, keine Kokken. Die Fadenbakterien sind auf dem Filter von kleinen Kokken angriffbar worden (Abb. 3).

Hier sind der Fulda Industrieabwässer zugeleitet worden. Das Wasser trägt stellenweise eine Ölschicht.

#### *Probe VII, 3.10.51, 10 Uhr 25*

10 m oberhalb der städtischen Abwasser-Einleitung.

Breite: 6 m; Tiefe: 70 cm; Strömungsgeschw.: kaum meßbar.

Wassertemp.: 12,5°; pH: 7,3.

Ufer: Steiler Wiesenabbruch, Weidengesträuch, große Urtica-Parke.

Untergrund: Verschlammt, mit Grün- und Blaualgen überzogen.

Probenentnahme: Linkes Ufer, 30 cm tief.

Ergebnisse: Keimzahl in 1,0 ccm — 60.000

Bakt. coli in 1,0 ccm — 4.000

pathog. Keime in 1,0 ccm — nicht nachgewiesen.

Überwiegend Fadenbakterien (Abb. 4), große Stäbchen mit je 2 Sporen (Abb. 5) einzeln und in Gruppen. Dünne lange Stäbchen, Vibrionen und Spirillen.

Das Wasser ist trübe und mit einem Ölfilm bedeckt.

#### *Probe VIII, 3.10.51, 10 Uhr 45*

Abwassereinleitung bei Horas.

Breite: 7 m; Tiefe: 40 cm; Strömungsgeschw. 20 cm/sek.

Wassertemp.: 13,8°; pH 7,5.

Ufer: Steiler Wiesenabbruch, Urticabewuchs.

Untergrund: Schwarzer Sulfidschlamm, stetes Aufsteigen von Gärgasen.

Probenentnahme: Wenige Meter hinter dem Abwassereinlauf, 20 cm tief.

Ergebnisse: Keimzahl in 1,0 ccm — 160.000

Bakt. col. in 1,0 ccm — 7.000

pathog. Keime in 1,0 ccm — 6 Kolonien.

Hauptsächlich stäbchenförmige Bakterien mit reicher Koloniebildung (Abb. 6). Zum ersten Mal tritt *Bact. mycoides* auf. In der Minderzahl Vibrionen, Spirillen und Fadenbakterien, einige große Kokken und Sarcinen.

Das Abwasser strömt scheinbar aus zwei Rohren in der Breite des Flusses aus, hat starken Fäkalengeruch und ist entsprechend gefärbt.

*Probe IX* 3.10.51 11 Uhr 10

40 m unterhalb der vorigen Station.

Breite: 8 m; Tiefe: 30 cm; Strömungsgeschw. 80 cm/sek.

Wassertemp.: 13,6°; pH: 7,3.

Ufer: Flach, dicht mit *Urtica* bewachsen.

Untergrund: Mit *Sphaerotilus*-Schleim überzogene Steine.

Probeentnahme: Linkes Ufer 20 cm tief.

Ergebnisse: Keimzahl in 1,0 ccm — 33.000

Bakt. coli in 1,0 ccm — 8.500

pathog. Keime in 1,0 ccm — 4 Kolonien.

Die Zusammensetzung des Bakterienplanktons wie in Probe VIII. *Bac. mycoides* bildet ebenfalls kleine Kolonien.

Im freien Wasser treiben Schmutzpartikel und *Sphaerotilus*-flocken. Der Nitratgehalt ist wie in der vorhergehenden Probe ungewöhnlich hoch.

*Probe X*, 3.10.51, 12 Uhr 40

Meandergebiet vor Gläserzell, etwa 4 Flußkilometer unterhalb der Abwassereinleitung.

Breite: 10 m; Tiefe: 2 m; Strömungsgeschw. 10 cm/sek.

Wassertemp.: 14°; pH: 7,4.

Ufer: Links steiler 2—3 m hoher Wiesenabbruch rechts dichter *Phragmites*-Ufergürtel.

Untergrund: Schwarz-grauer Schlamm, dichter Behang von *Sphaerotilus*-flocken typisches „Pilztreiben“.

Probeentnahme: Rechtes Ufer, 1 m tief.

Ergebnisse: Keimzahl in 1,0 ccm — 84.000

Bakt. coli in 1,0 ccm — 22.000

pathog. Keime in 1,0 ccm — 3 Kolonien.

Es überwiegen wieder stäbchenförmige Bakterien. Vibrionen, Spirillen und *Bakt. mycoides* wie in den vorhergehenden Proben, Fadenbakterien etwas häufiger. Kokken nur vereinzelt.

*Probe XI*, 3.10.51, 13 Uhr 30

1 km unterhalb Gläserzell.

Breite: 25 m; Tiefe: 1 m; Stauwasser

Wassertemperatur: 14,0°; pH: 7,3.  
 Ufer: Weideland, Erlen- und Weidenbewuchs.  
 Untergrund: Mit Schlamm überzogen, vereinzelt Sphaerotilusflocken.  
 Probeentnahme: Rechts Ufer, 50 cm tief.  
 Ergebnisse: Keimzahl in 1,0 ccm — 19.000  
               Bakt. coli in 1,0 ccm — (überwachsen)  
               pathog. Keime in 1,0 ccm — nicht nachgewiesen.  
 Bac. mycoides ist noch häufiger geworden. Stäbchen und Fadenbakterien vorhanden, vereinzelt Vibrionen und Kokken.

*Probe XII, 3.10.51, 14 Uhr 10*

1 km vor Lüdermünd  
 Breite: 20 m; Tiefe: 1,5 m; Strömungsgeschw. 15 cm/sek.  
 Wassertemp.: 14,6°; pH: 7,3.  
 Ufer: Links Niederwald mit breiter Phragmiteszone. Rechts Weidenland.  
 Untergrund: Steinig, verschlammt, Sphaerotilusflocken.  
 Probeentnahme: Rechtes Ufer, 50 cm tief.  
 Ergebnisse: Keimzahl in 1,0 ccm — 18.000  
               Bakt. coli in 1,0 ccm — 180  
               pathog. Keime in 1,0 ccm — nicht nachgewiesen.  
 Vorwiegend hefeartige Zellen, einzeln und in Ketten, die an Pseudomycete erinnern. Weiterhin haben sich Kolonien von Stäbchen mit Sporen gebildet. Kokken, Vibrionen und Spirillen nur vereinzelt.

*Probe XIII, 4.10.51, 9 Uhr 30*

Lüder, 100 m vor der Mündung in die Fulda.  
 Breite: 8 m; Tiefe: 50 cm; Strömungsgeschw. 40 cm/sek.  
 Wassertemp.: 10,4°; pH: 7,2.  
 Ufer: Rechts steiler Abhang, Buchenwald, links Wiese, Phragmiteszone.  
 Untergrund: Basaltgeröll, Ranunc. fl. und Elodea can.  
 Probeentnahme: Flußmitte, 30 cm tief.  
 Ergebnisse: Keimzahl in 1,0 ccm — 800  
               Bakt. coli in 1,0 ccm — 10  
               pathog. Keime in 1,0 ccm — nicht nachgewiesen.  
 Kokken, die teilweise Kolonien gebildet haben, herrschen vor (Abb. 7 u. 8). Dünne lange Stäbchen ebenfalls häufig. Fadenbakterien, Vibrionen und Spirillen können nicht nachgewiesen werden. Das Wasser der Lüder ist außerordentlich klar und läßt dem Augeneinblick nach auf keinerlei Verunreinigung schließen.



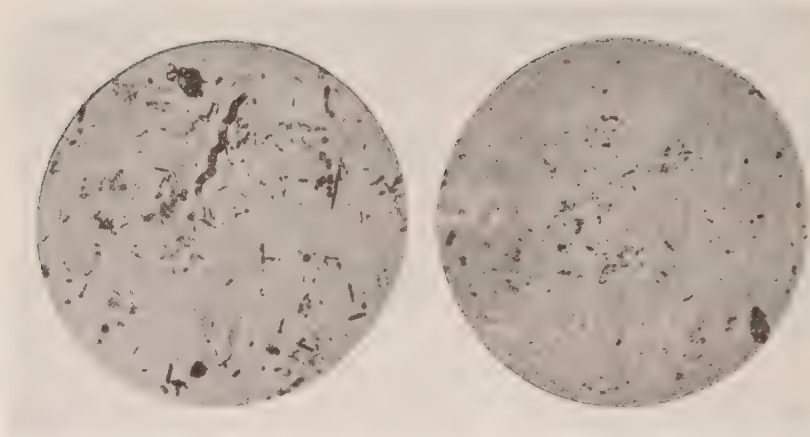


Abb. 1 und 2 (nach Radzimowski)

*Probe XIV, 4.10.51, 9 Uhr 50*

Fulda, 500 m unterhalb der Lüdermündung.

Breite: 20 m; Tiefe: 2 m; Strömungsgeschw. 50 cm/sek.

Wassertemp.: 10,1°; pH 7,1.

Ufer: Rechts Weideland mit breitem Phragmitesgürtel, links Buchenwald.

Untergrund: Basaltschotter, wenig verschlammt.

Probeentnahme: Linkes Ufer, 50 cm tief.

Ergebnisse: Keimzahl in 1,0 ccm — 1.500

Bakt. coli in 1,0 ccm — 107

pathog. Keime in 1,0 ccm — nicht nachgewiesen.

Stäbchen und Kokken fast in gleicher Menge vorhanden; reichliche Fadenbakterien, selten dagegen Vibrionen und Spirillen.

(Das Bild der Probe scheint auf eine ungenügende Vermischung des Fuldawassers mit dem der Lüder zurückzuführen zu sein. Mündung und Probeentnahmestation lagen beide am linken Ufer und nur 500 m auseinander. Sichtbare „Bandbildungen“ verschmutzender Gewässer sind eine bekannte Erscheinung.)

*Probe XV, 4.10.51, 10 Uhr 30*

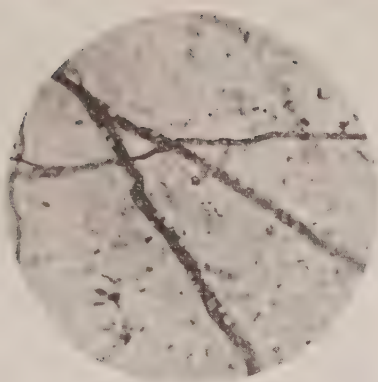
12 km unterhalb der Abwasserzuführung bei Horas.

Breite: 15 m; Tiefe: 3 m; Strömungsgeschw. 5 cm/sek.

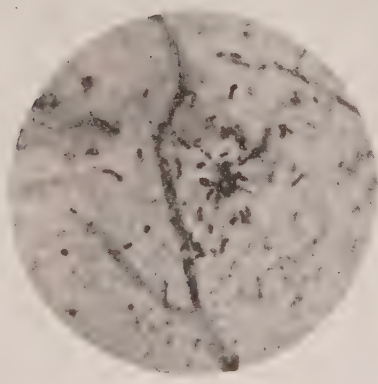
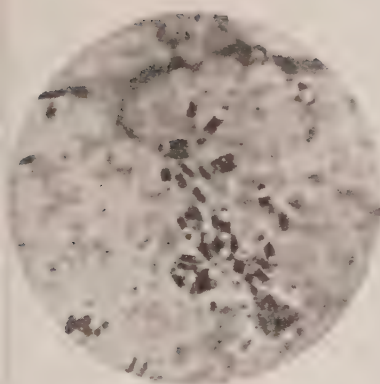
Wassertemp.: 10,1°; pH: 6,9.

Ufer: beiderseitig steiler Wiesenabbruch.

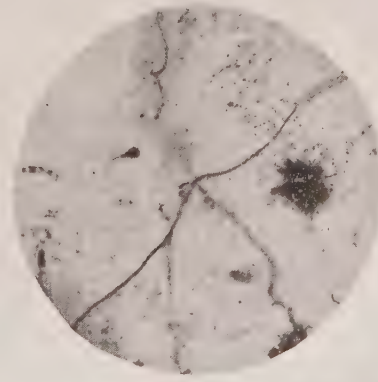
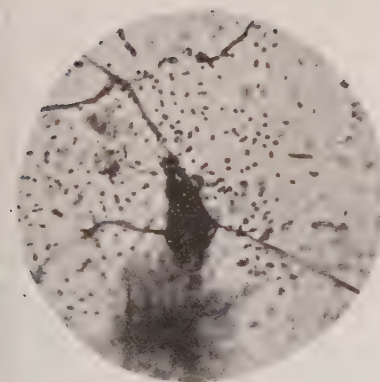
Untergrund: Steinig, mit großen Feldern von Ranunc. fl. überzogen.



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6



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Probeentnahme: Rechtes Ufer, 50 cm tief.

Ergebnisse: Keimzahl in 1,0 ccm — 250

Bakt. coli in 1,0 ccm — 30

pathog. Keime in 1,0 ccm — nicht nachgewiesen.

Nur Kokken und sehr kleine Stäbchen.

*Probe XVI, 4.10.51, 12 Uhr*

3 km oberhalb von Pfordt.

Breite: 15 m; Tiefe: 1,5 m; Strömungsgeschw. 50 cm/sek.

Wassertemp.: 12,2°; pH: 6,8.

Ufer: Beiderseitig Wiesenabbruch mit dichtem Weidengesträuch.

Untergrund: Steinig, Ranunc. fl.

Probeentnahme: Rechtes Ufer, 50 cm tief.

Ergebnisse: Keimzahl in 1,0 ccm — 110

Bakt. coli in 1,0 ccm — 6

pathog. Bakt. in 1,0 ccm — nicht nachgewiesen.

Kokken überwiegen deutlich. An einigen Stellen haben sie winzige Kolonien gebildet, ebenso kleine Stäbchen und Kokkobazillen. Andere Formen wurden nicht beobachtet.

*Probe XVII, 4.10.51, 12 Uhr 40*

5 km unterhalb von Pfordt.

Breite: 20 m; Tiefe 2 m; Strömungsgeschw. 30 cm/sek.

Wassertemp.: 13,5°; pH 7,0.

Ufer: Flaches Weideland auf beiden Seiten.

Untergrund: Steinig, verschlammt.

Probeentnahme: Rechtes Ufer, 40 cm tief.

Ergebnisse: Keimzahl in 1,0 ccm — 1550

Bakt. coli in 1,0 ccm — 10

pathog. Keime in 1,0 ccm — nicht nachgewiesen.

In der Mehrzahl finden sich wieder stäbchenförmige Bakterien, vereinzelt Vibrionen und Spirillen, Kokken selten.

Für eine erneute Verunreinigung der Fulda können hier die Abwässer des Ortes Pfordt verantwortlich gemacht werden.

Um einen Überblick zu geben, faßten wir die chemischen und bakteriologischen Daten sowie den Charakter des Bakterienplanktons in einer Tabelle zusammen (Tab. 2), wobei sich eine erstaunliche Übereinstimmung der Werte ergibt.

Es zeigt sich, daß die chemischen Analysen parallel zu dem Verschmutzungsgrad des Wassers einen entsprechenden Gehalt an Ammoniak, Nitriten Nitraten sowie Schwefelwasserstoff und Sauerstoff ergeben (s. Proben V—XII). Wir nehmen an, daß an diesen abwasserführenden Flußabschnitten die Zersetzung der organischen

Stoffe in vollem Gange ist. Die weiteren Proben zeigen, daß der Selbstreinigungsprozeß stetig vor sich geht. Der Einfluß der Lüder, die bei einer großen Wasserführung relativ sauberes Wasser hat, macht sich eindeutig bemerkbar. Die Gesamtwassermenge steigt erheblich an, wobei das verschmutzte Fuldawasser verdünnt und der Reinigungsprozeß beschleunigt wird. Die folgende Proben lassen vermuten, daß weiter flußabwärts keine größeren Abwassermengen mehr eingeleitet worden sind mit Ausnahme des Flußabschnittes unterhalb des Dorfes Pfordt.

Das Bakterienplankton ist mengenmäßig ebenfalls in Tab. 2 angegeben, wobei das Quantum der einzelnen Bakterienformen wie folgt bezeichnet wird:

- ++++ überwiegend
- +++ in der Mehrzahl
- ++ reichlich
- +
- vereinzelt
- nicht nachgewiesen.

Für die Keimzahlbestimmung kamen nur die Werte der Plattenmethode in Betracht, da die Direktmethode, wie schon erwähnt, durch die Vermehrung der Mikroorganismen auf den Filtern ausfiel.

Wir mußten uns daher auf die morphologische Beschreibung des Bakterienplanktons beschränken.

Eine rege Vermehrungstendenz auf den Filtern zeigten Stäbchen und kokkenförmige Bakterien. Eine Kolonieentwicklung der Vibrionen und Spirillen konnte nicht festgestellt werden. Diese Formen waren nur einzeln aufzufinden. Verschiedene Arten von Actinomyeten, Monilia u.a. entwickelten sich üppig, wobei wir darauf hinweisen möchten, daß es selbstverständlich unmöglich ist, die Bestimmung der einzelnen Bakterienarten auf Grund eines morphologischen Befundes vorzunehmen.

Mit Hilfe der direkten Membranfilter-Methode zeigten wir, daß im Durchschnitt in verunreinigtem Wasser stäbchenförmige Bakterien vorherrschen, während ein Überwiegen der Kokken für relativ sauberes Wasser charakteristisch zu sein scheint. Die Proben IV—II geben den ersten Typ wieder. Dazu kommt noch der Nachweis von Vibrionen, Spirillen und Fadenbakterien. Die Aufzeichnung der äußerlich sichtbaren Verunreinigung des Flusses sowie die Ergebnisse der chemischen Untersuchungen sprechen für diese Feststellungen. Die genannten Formen des verunreinigten Wassers treten vorwiegend in Massen auf, wo der Zersetzungsprozeß organischer Stoffe vor sich geht.

Die Tatsache, daß das Vorkommen charakteristischer Bakterienformen vom Verschmutzungsgrad des Wassers abhängig ist, reicht



jedoch umgekehrt bei weitem nicht aus, diesen auf Grund einer Untersuchung des morphologischen Bildes der Bakterienflora endgültig zu bestimmen. Je kleiner ein Organismus, der als Leitform für das Saprobiensystem gelten soll, und je kleiner sein physiologischer Lebensraum ist, desto größer ist die Rolle des Zufalls. Fremdinfektionen und eine zeitlich nur kurze Veränderung des Milieus an den Mikrostandorten können das wahre Gesamtbild verfälschen. Ebenfalls ist es noch nicht zu übersehen, inwieweit die Strömungen des Wassers die verschiedenen Formen von ihrem jeweiligen Milieu trennen und mit anderen vermischen können, und wie lange sie sich dann unter den verschiedenartigsten Einflüssen für die Direktmethode kenntlich erhalten. Obwohl alle diese Dinge bei der Probenentnahme berücksichtigt werden können, kann ein vollständig abgerundetes Charakterbild eines Gewässers nur gewonnen werden, wenn sämtliche Disziplinen der Hydrobiologie herangezogen werden.

Wenn auch alle diese Untersuchungen noch den Charakter des Vorläufigen haben, so scheint uns doch die Annahme berechtigt, daß die Anwendung der Membranfilter-Methode neue Möglichkeiten bietet, diesen so überaus schwierigen Problemen der Rolle der Mikroorganismen in der Biozönose eines Gewässers näher zu kommen.

## ZUSAMMENFASSUNG

Es wurde mit Hilfe der kulturellen und der direkten Membranfilter-Methode ein Flussabschnitt der Fulda, der sich durch starke Abwasserführung auszeichnete, bakteriologisch untersucht. Bei der direkten mikroskopischen Zählung der Bakterien auf den Filtern wurden Zahlen gefunden, die die des Koch'schen Plattenverfahrens um das 10 bis 50-fache überstiegen. Das Studium der Bakterienformen in den verschiedenen filtrierten Proben läßt bei dem Vergleich mit den parallelen Untersuchungen — mit entsprechenden Vorbehalten — Schlüsse auf die Beziehungen zum Verschmutzungsgrad des Wassers zu.

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# The Fresh-Water Algae of Montana. I.

## New Species of Chaetophoraceae

G. W. PRESCOTT

Few published reports have appeared which deal with the algal flora of Montana where, especially in the western and mountainous sections, there are many suitable habitats for these plants. One of the more productive regions is in the valley occupied by Flathead Lake. This is a relatively large body of water lying along the west side of the picturesque Mission Mountains mostly in Lake County. The lake is approximately 40 miles in length, and averages 7 miles in width, being formed in part by the Flathead River. The valley is a glacial one and the lake is bounded on its southern extremity by a terminal moraine.

Beyond the moraine the valley, once occupied by an ancient inland sea, continues as a rolling till plain, abundantly beset with shallow ponds, sinks, and swamps. Whereas the ponds and pools overlie the same soil type, and are subjected to the same edaphic factors, the algal flora varies decidedly one from another. In some ponds the water is slightly acid (pH 6.8) and desmids predominate. In others, especially in the reservoir lakes in the lower part of the valley (southern end) some 20 miles from the south shore of Flathead Lake, the water is basic and diatoms, blue-green, and basiphilic green algae such as *Hydrodictyon*, *Cladophora*, and *Rhizoclonium* predominate. Except for diatoms, Flathead Lake itself is almost an algal desert.

Among the new or otherwise interesting species of algae collected in this region are three apparently new members of the Chaetophoraceae.

### *Draparnaldiopsis salishensis* sp. nov. \*) <sup>1)</sup>

Thallus an axis of quadrate or short cylindrical cells alternating with very short, disciform cells which bear a whorl of 3-4 fascicles of

\*) The author is grateful to Dr. HANNAH CROASDALE for her assistance in preparing the Latin diagnoses.

<sup>1)</sup> Thallus axis e cellulis quadratis aut brevi-cylindricis alternantibusque brevissimis disciformibus compositus, his verticillum 3—4 fascicularum ramorum

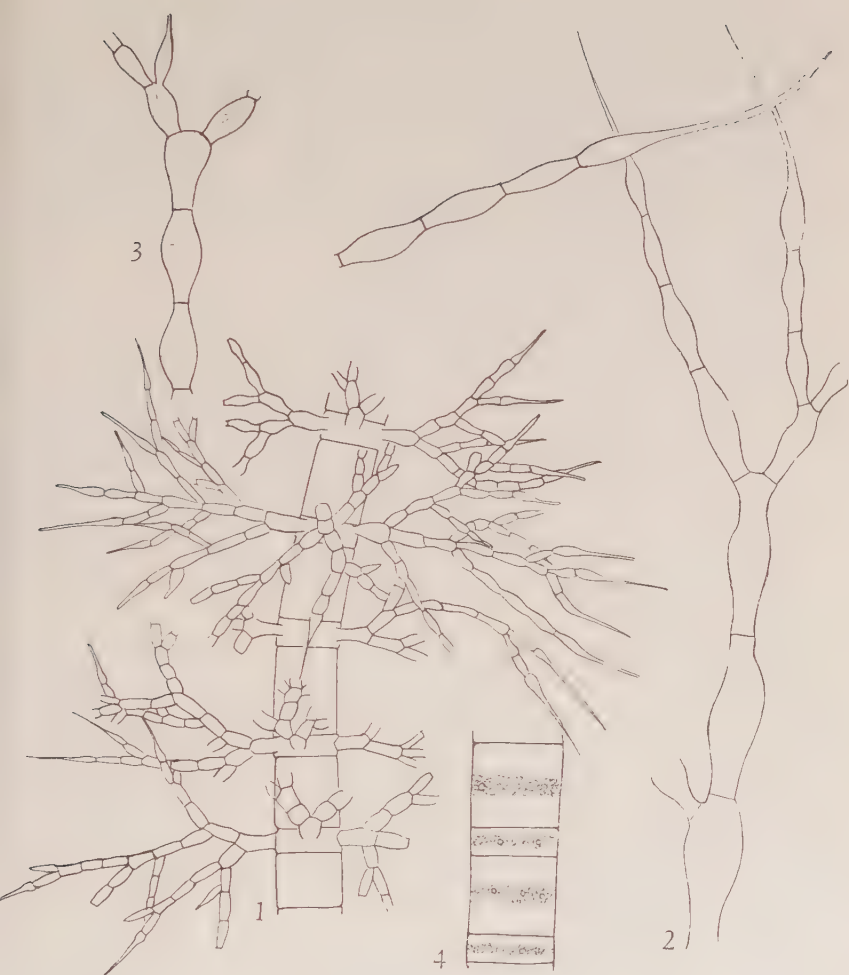


Plate I

*Draparnaldiopsis salishensis* sp. nov.

- Fig. 1. Habit of portion of main axis.  
 Fig. 2—3. Individual branches of fascicle.  
 Fig. 4. Cells of main axis with chloroplast



branches composed of cells much smaller than those of the main axis; branches irregularly dichotomous or trichotomous, the cells fusiform, capitate, or repand, and terminating in long setae with bulbous bases; chloroplasts in the main axial cells a narrow parietal ring containing several pyrenoids, in the cells of the branches occurring as single or as 2 parietal plates each with a pyrenoid; main axial cylindrical cells 20—23  $\mu$  in diameter, 25—35  $\mu$  long; branch-bearing cells of the main axis about one-fifth as long as the cylindrical cells; cells of the branches 5—8—(10)  $\mu$  in diameter; filaments imbedded in a copious, very soft and formless mucilage. Pl. I.

Clinging about submerged aquatic plants in Turtle Lake, 1½ miles south of Flathead Lake, Montana. July, 1950, 1951.

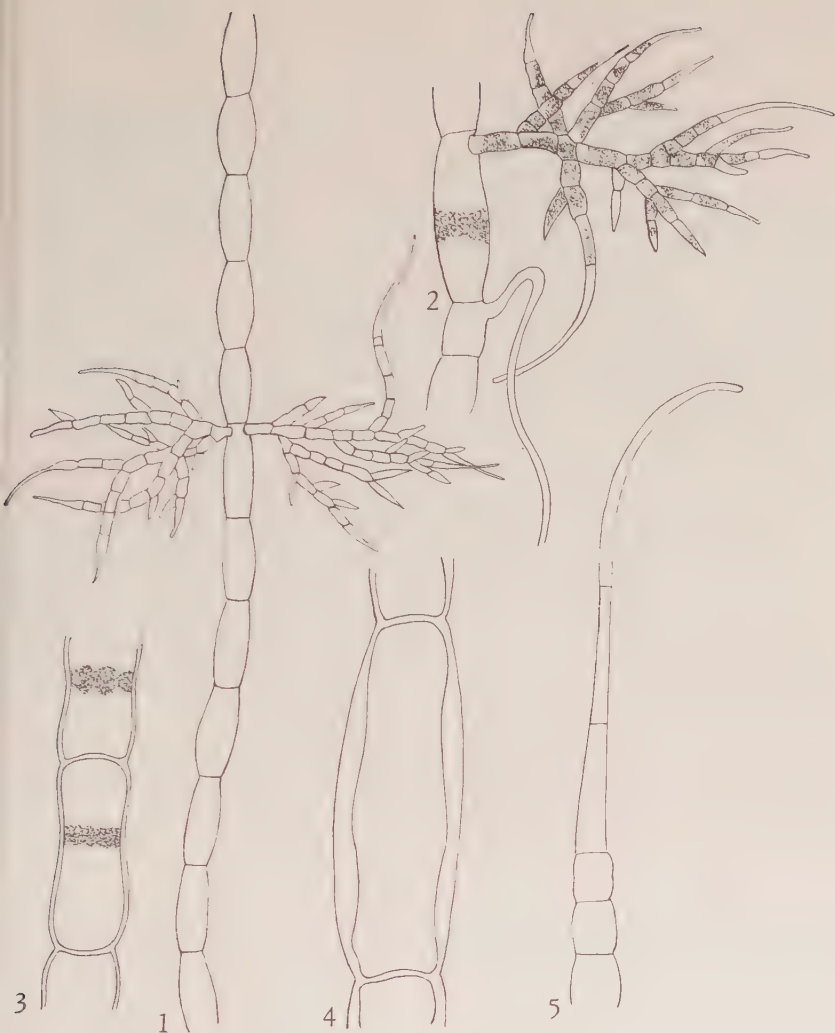
The habitat where this species was collected is a small lake used for irrigation. The water level fluctuates greatly during the season as the outlet gate is lowered or opened. The plants make their appearance early in July and are at first very sparse. By early August the submerged vegetation in shallow water is veritably coated with soft, mucilaginous thalli and the algae may be stripped from their substrates by handfuls. Scarcely any other algae occur in the lake which is fed by a small stream of basic water. The elevation is about 3000 feet above sea level.

This genus was described originally from a subalpine station in California by G. M. SMITH and F. D. KLYVER as *D. alpina*. Another species (*D. indica*) has been reported from India by BHARADWAJA. The Montana plant differs from both of the other species in its habit of branching, which is mostly whorled, and in the manner of branch origin and structure. The cells of the branches are mostly tumid, rather than cylindrical, and some are definitely fusiform. The setae with bulbous bases constitute another character which is different from the other described species. The chloroplast of the main axial cell is a plain band and not lacinate.

Although numerous swarming, gamete-like cells were observed, and although these were occasionally seen to be in contact with one another, actual union was not detected. The motile elements are

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e cellulis multo minoribus quam cellulis axis principalis compositorum ferentibus; rami irregulariter dichotomi aut trichotomi, cellulae fusiformes capitatae aut repandae, in setas basibus bulbosis praeditas desinentes; chloroplastus in cellulis axis principalis anulus angustus parietalisque pyrenoidea aliquot continens, in cellulis ramorum chloroplasti velut laminae 1—2 parietales existentes, omnibus pyrenoideo praeditis; cellulae cylindricae axis principalis 20—23  $\mu$  diam., 25—35  $\mu$  long.; cellulae ramiferae axis principalis magnitudine circa quintae partis cellularum cylindricarum; cellulae ramorum 5—8—(10)  $\mu$  diam.; filamenta in mucilagine inclusa copiosa mollissima sine forma.



## Plate II

*Draparnaldia sparsifasciculata* sp. nov.

- Fig. 1. Habit of main axis showing sparsely arranged fascicles.  
 Fig. 2. One fascicle and rhizoidal branch.  
 Fig. 3. Panduriform cells of the branches.  
 Fig. 4. Cell of main axis with thickened lateral walls  
 Fig. 5. Setiferous tip of fascicle branch.

formed in undifferentiated cells in the median part of the branches, not in the terminal cells.

*Draparnaldia sparsifasciculata* sp. nov. <sup>2)</sup>

Thallus consisting of an axis of tumid cells, much constricted at the cross walls, bearing alternate or opposite fascicles of branches of much smaller cells, the fascicles remote from those above and below; cells of the branches tumid or panduriform, the apices setiferous, sometimes with flagelliform cells which are bluntly tipped; chloroplast of the main axial cells a narrow, parietal band with undulate margins; pyrenoids 3 to several; chloroplast in the branch cells a parietal plate, nearly or quite covering the wall; cells of the main axis 20—25—(40)  $\mu$  in diameter, 56—75—(80)  $\mu$  long; thallus imbedded in a soft, watery and scarcely discernible mucilage. Pl. II.

Attached to submerged grasses in a small pond in lower Mission Valley (Nine Pipes Reservoir district), Montana. July, 1951.

The chief characteristic of this plant is the slender axis of tumid cells bearing remotely arranged and rather sparsely branched fascicles. The panduriform or repand cells are unlike any other described species. The main axis was not observed to have secondary branches of unlimited growth which are commonly found in other species of *Draparnaldia*. Near the base of the filaments downward-projecting, colorless rhizoidal cells are found. Some of the axial cells near the base have very much thickened lateral walls.

The pond where this species was collected is acid and contains a fairly rich desmid flora, together with many chlorococcalean species. The elevation is about 3000 feet above sea level.

*Stigeoclonium Nelsonii* sp. nov. <sup>3)</sup>

Filaments long and sparingly and loosely branched, the main axes composed of cylindrical or subcylindrical cells, bearing alternate and irregularly arranged fascicles composed of cells slightly smaller than

<sup>2)</sup> Thallus ex axe compositus cellularum tumidarum ad dissaepimenta multum constrictus, fasciculus alternas oppositasve ramorum e cellulis multo minoribus compositorum ferens; fasciculis ab eis superis inferisque remotis; cellulae ramorum tumidae panduriformesve, apicibus setiferis, cellulas flagelliformes, cacuminibus obtusis praeditas interdum habentibus; chloroplastus cellularum axis principalis taenia angusta parietalis, margines undulatos praebens, 3 aut plura pyrenoidea habens; chloroplastus cellularum ramorum lamina parietalis, membranam aut onmino aut magna ex parte obducens; cellulae axis principalis 30—25—(40)  $\mu$  diam., 56—75—(80)  $\mu$  long., thallus in mucilagine molli, aquosa, vix distinguibili inclusus.

<sup>3)</sup> Filamenta longa, parce laxaque ramosa, axes principales e cellulis cylindricis aut subcylindricis compositi, cellulis fasciculas alternas irregulariter dispositas, e cellulis paulo minoribus quam cellulis axis principalis compositas, ferentibus,

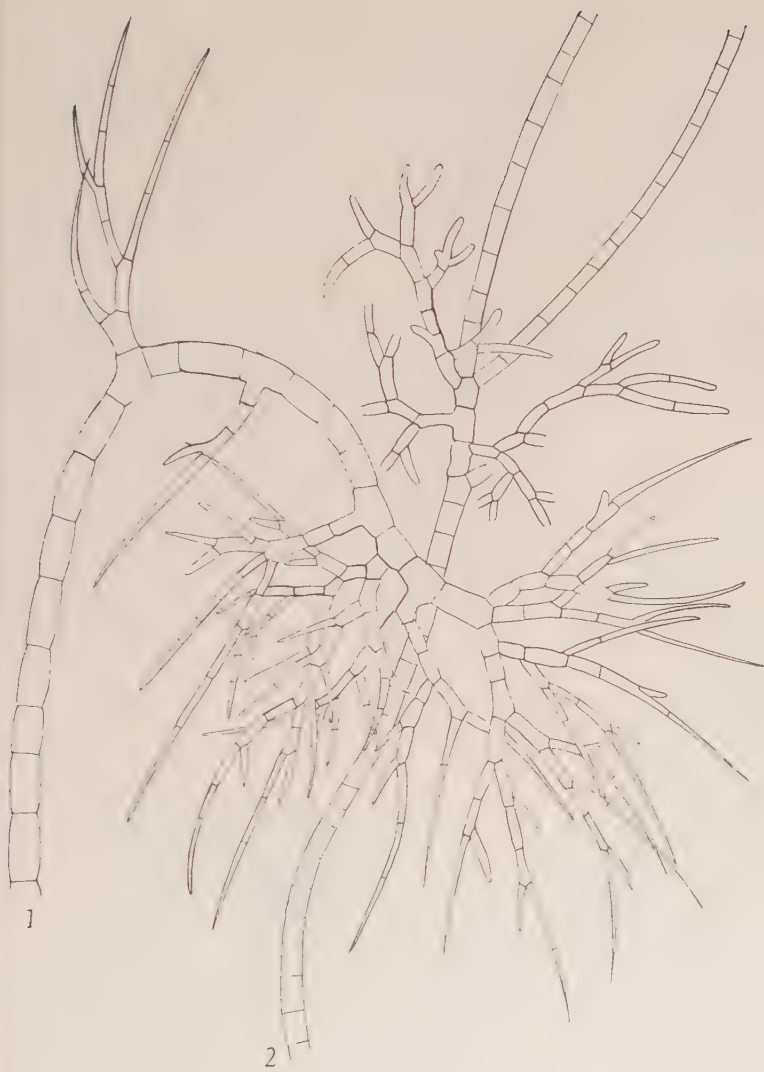


Plate III

*Stigeoclonium Nelsonii* sp. nov.

- fig. 1. Apex of main axis showing fascicles of branches.  
 fig. 2. Portion of main axis near base of thallus.



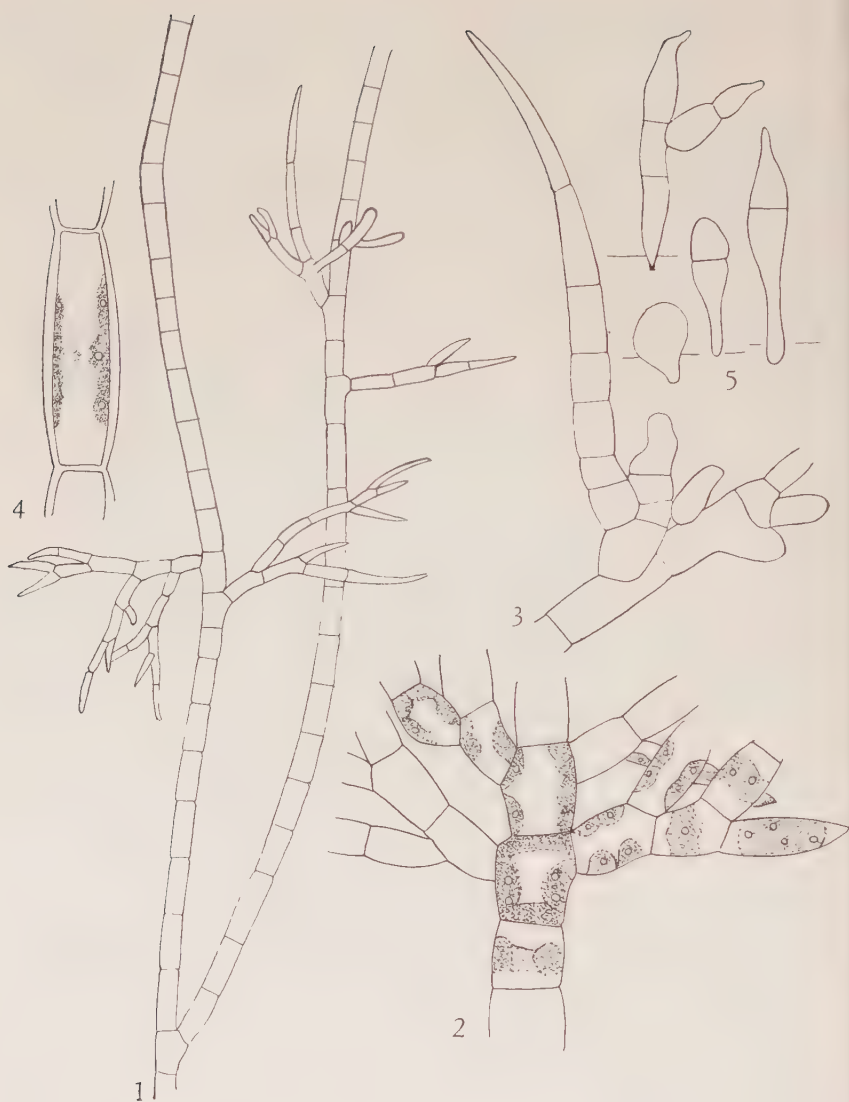


Plate IV

*Stigeoclonium Nelsonii* sp. nov.

- Fig. 1. Habit of thallus  
 Fig. 2. Origin of branches from main axis.  
 Fig. 3. Portion of branch in detail.  
 Fig. 4. Cell of main axis showing chloroplast.  
 Fig. 5. Germlings.

those of the main axis, the branches ending in sharply pointed, or sometimes bluntly pointed or spatula-shaped cells; main axis terminating in a fascicle with several subterminal cells giving rise to a fascicle of branches; chloroplast an incomplete and wide parietal band in the cells of the main axis, a band or parietal plate in the cells of the branches; main axial cells 20—36  $\mu$  in diameter, 3—5 times the diameter in length. Pl. III, IV.

On the shell of a dead snail, floating in a small pond (Black Tern Pond)

ramis in cellulas acute, aut interdum obtuse acuminatas, aut spathiformes terminantibus; axis principalis terminans in fasciculam aliquot cellulas subterminales, fasciculam ramorum vicissim effecentes, habentem; chloroplastus in cellulis axis principalis taenia aut lamina parietalis; cellulae axis principalis 20—26  $\mu$  diam., 3—5 plo longiores quam latae.

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# A new Species of *Anabaenopsis* in a Kansas Lake with notes on Limnology

G. W. PRESCOTT<sup>1)</sup> and TED F. ANDREWS<sup>2)</sup>

Wooster Lake is a shallow, basic pond on the campus of Kansas State Teachers College at Emporia. The pond is young, having existed but 13 years, is about 2 acres in surface area, has a maximum depth of about 12 feet and a mean depth of 6 feet. It is, therefore, subject to complete overturn and develops a relatively high surface temperature (September 26, 25.9° C. e. g.). But there is a large temperature gradient from surface to bottom during most of the time except when there is an ice cover.

The chemical nature of the water and the high temperature are favorable for the development of blue-green algal blooms. The fertilizing nutrients are amply provided by drainage from the surrounding populated area, from the overflow of a college swimming pool, and from a storm-sewer drainage. The lake is fed principally by springs at the bottom and is relatively clear (less than 30 ppm. turbidity). There is scarcely any vegetation other than *Typha latifolia* L., *Nymphaea odorata* Ait., and *Dianthera americana* L.

The limnological characteristics, in general rather constant throughout the year, are shown in Table I which presents data taken weekly

TABLE I.

Mean limnological characteristics of Lake Wooster ascertained from weekly samples taken during October and November, 1951

	Temp. in Deg. C.	pH	CO <sup>2</sup> ppm.	O <sup>2</sup> ppm.	Ph'th. Alk.ppm.	M-O Alk.ppm.	Total Hard. ppm.	Total Sest. mg/L	Total Organ. Sest. mg/L
Oct. Surface	20.4	8.6	0.4	12.7	4.4	79	135	18.7	7.4
Bottom	16.2	8.1	5.4	5.8	0.0	87	136	28.8	7.6
Nov. Surface	7.1	8.2	6.0	4.0	0.0	90	131	12.7	4.6
Bottom	6.2	7.9	5.2	3.3	0.0	94	138	16.7	5.5

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<sup>2)</sup> Department of Zoology, Kansas State College.

during October and November, 1951. In October the surface temperature varied from 26.1° C. on October 3, to 14° C. on October 25, while at the same time the bottom temperature ranged from 17.9° C. to 13.1° C. The water chemistry, pH and electrolytes, remain somewhat uniform but it is significant that CO<sub>2</sub> usually present at the bottom is almost lacking near the surface.

On September 25, 1951, there developed a dense algal bloom which was similar in appearance to those formed by *Aphanizomenon flos-aquae* L. or by *Microcystis aeruginosa* KUETZ., presenting a thick, surface scum. Upon examination, however, the alga proved to be *Anabaenopsis* and to have characteristics which warrant its description as a new species. The bloom endured as a scum for two days and then disintegrated, coloring the water a greenish-yellow. The day after the peak of the bloom (September 26) the lake possessed limnological characteristics shown in Table II.

TABLE II.

Limnological characteristics of Wooster Lake, September 26, the day following the peak of *Anabaenopsis* bloom.

	Temp. in deg.C.	pH	CO <sub>2</sub> ppm.	Ph'th. Alk.ppm.	M-O Alk.ppm.	O <sub>2</sub> ppm.
Surface	25.9	8.4	0	3	81	13
Bottom	18.0		6	0	90	1.5

*Anabaenopsis seriata* Presc., sp. nov.<sup>1)</sup>

Trichomes solitary or entangled, short, straight or slightly curved, up to 80  $\mu$  in length, tapering at one or at both ends, never coiled; cells cylindrical, not constricted at the cross walls, cell-contents blue-green, finely and densely granular; heterocysts conical, terminal, at one or rarely at both ends of the trichome, 3  $\mu$  in diameter, 4.6-5  $\mu$  long; akinetes oval to cylindrical, solitary or in a terminal series (2-5) adjacent to the heterocysts, 3-3.5  $\mu$  in diameter, 9-16  $\mu$  long, contents coarsely granular; vegetative cells 2.5-2.8  $\mu$  in diameter, 7.5-10  $\mu$  long. Figs. 1-3.

<sup>1)</sup> Trichomata singularia aut implicata, brevita ad 80  $\mu$  longitudine, recta aut subcurvata, numquam helicoidea; cellulae cylindricae, ad dissaepimenta non constrictae, intus coerulo-virides, subtiliter denseque granulosae; heterocystes conicae, terminales, ad unam aut raro ad utramque extremitatem trichomatis, 3  $\mu$  diam., 4.5-5-(8)  $\mu$  long.; akineta ovata ad cylindrica, singularia aut in serie terminale (2-5), contingentia ad heterocystes, 3-3.5  $\mu$  diam., 9-16  $\mu$  long., intus grosse granulosa; cellulae vegetativae 2.5-2.8  $\mu$  diam., 7-10  $\mu$  long.

The authors are grateful to Dr. HANNAH CROASDALE for her assistance in the preparation of the Latin diagnosis of *Anabaenopsis seriata*.



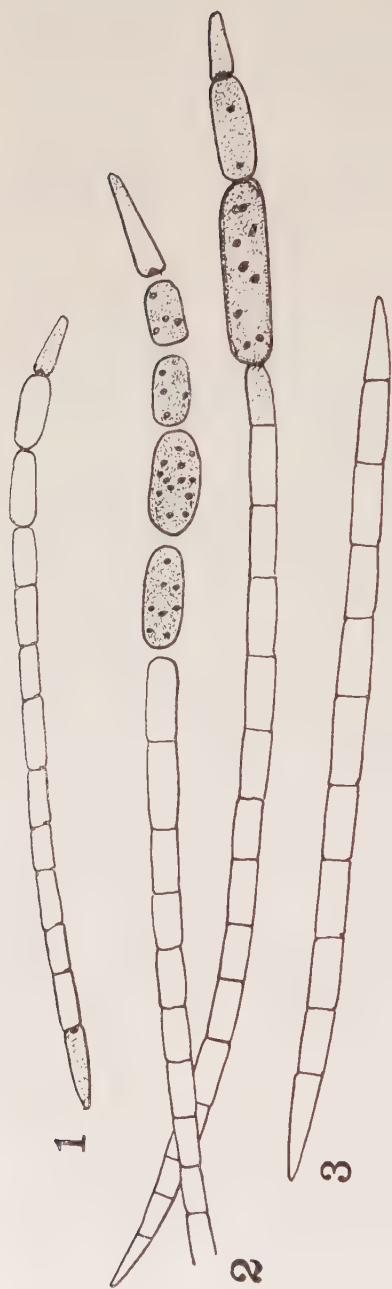


Fig. 1. Young trichome with heterocysts at both ends  
 2. Mature trichomes with akinetes  
 3. Young trichome with apical cells tapering.

Plankton in Wooster Lake, Emporia, Kansas. September water bloom.

This species has some characteristics in common with *A. Raciborskii* Wolosz. which was described from a lake in Java. That plant may have straight trichomes but has cells constricted at the cross walls and differently shaped heterocysts. The akinetes are unknown for *A. Raciborskii*. In preservative the collections of *A. seriata* become a bright marine-green color.

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# A Note on the Occurrence of *Hexarthra fennica* LEVANDER in Czechoslovakian Oligohaline Waters

By

VLADIMÍR SLÁDEČEK.

In the northeastern part of Moravia in the vicinity of the town of Moravská Ostrava (a part of the former territory of Silesia), three new habitats of the Rotifer *Hexarthra fennica* LEVANDER were found in June, 1950 and August, 1951. This is the first record dealing with this species in Czechoslovakia, since the discovery of the near related species *Hexarthra oxyuris* ZERNOV by KOHL (1942) in the salt waters of Soos (western Bohemia).



The specimens from the silesian ponds Nový Stav, Heřmanský and Lesník are well developed and belong to the typical species as described by LEVANDER (1892, 1894) from Finland. See figs 1—6.

Measurements: Length of the trunk 125—150  $\mu$ , height of trunk 55  $\mu$ , length of the ventral arm 125  $\mu$ , length of the bifurcate filamentous appendages on this arm 100  $\mu$ , length of the dorsal arm 85—90  $\mu$ , length of its bifurcate filamentous appendages 40—80  $\mu$ . Dental formula 7/7. Stylate appendages, sabreshaped cuticular appendage on the trunk and lower lip lacking. No transitory specimens to the species (or variety?) *oxyuris* ZERNOV were observed.

The zooplankton of the three ponds in which *Hexarthra fennica* occurs consists of the following species:

Pond Nov ý Stav, June 10th, 1950 (leg. Dr B. FOTT):

*Rotatoria*: *Brachionus plicatilis* O. F. MÜLLER (abundant), *Hexarthra fennica* LEV. (abundant), *Keratella stiptata* EHRENBERG, *Rotatoria contracta* g. sp.

*Cladocera*: *Daphnia pulex* DEGEER (abundant).

*Copepoda*: nauplii (abundant), copepodits (abundant), *Cyclops* *Cyclops strenuus* FISCHER.

Pond Nov ý Stav, August 13th, 1951 (leg. Dr V. SLÁDEČEK):

*Rotatoria*: *Brachionus plicatilis* O. F. M., *Brachionus rubens* EHRBG., *Hexarthra fennica* LEV. (abundant), *Keratella quadrata dispersa* CARLIN, *Notholca acuminata* EHRBG., *Polyarthra vulgaris* CARLIN (abundant).

*Cladocera*: *Ceriodaphnia quadrangula* O. F. M., *Daphnia pulex* DEGEER (abundant), *Scapholeberis mucronata* O. F. M.

*Copepoda*: nauplii (abundant), copepodits (abundant), *Eudiaptomus vulgaris* SCHMEIL.

The brackish water diatom *Bacillaria paradoxa* GMELIN was determined by Doctor B. FOTT from this sample.

Pond Les ník, June 9th, 1950 (leg. B. FOTT):

*Rotatoria*: *Brachionus plicatilis* O. F. M., *Keratella quadrata quadrata* CARLIN.

*Cladocera*: *Bosmina longirostris* O. F. M., *Chydorus sphaericus* O. F. M., *Daphnia magna* STRAUS (abundant), *Scapholeberis mucronata* O. F. M.

*Copepoda*: nauplii (abundant), copepodits (abundant).

Pond Les ník, August 13th, 1951 (leg. V. SLÁDEČEK):

*Rotatoria*: *Brachionus plicatilis* O. F. M., *Hexarthra fennica* LEV. (abundant), *Hexarthra mira* HUDSON, *Keratella quadrata quadrata* CARLIN, *Monostyla bulla* GOSSE, *Monostyla closterocerca* SCHMARDA, *Polyarthra vulgaris* CARLIN (abundant), *Testudinella patina* O. F. M.



*Cladocera*: *Ceriodaphnia quadrangula* O. F. M., *Chydorus sphaericus* O. F. M., *Daphnia longispina* O. F. M.  
*Copepoda*: nauplii (abundant), copepodits (abundant), *Cyclops* *Cyclops vicinus* ULJANIN.

Pond Heřmanský, June 19th, 1950 (leg. B. FOTT):

*Rotatoria*: *Brachionus rubens* EHRBG., *Hexarthra fennica* LEV. (abundant), *Keratella quadrata quadrata* CARLIN, *Keratella stipitata* EHRBG., *Notholca acuminata* EHRBG., *Polyarthra vulgaris* CARLIN (abundant).

*Cladocera*: *Ceriodaphnia* sp. juv., *Chydorus sphaericus* O. F. M.

*Copepoda*: nauplii (abundant), copepodits (abundant).

Pond Heřmanský, August 13th, 1951 (leg. V. SLÁDEČEK):

*Rotatoria*: *Brachionus calyciflorus* PALLAS (f. *dorcas*), *Brachionus urceus* L., *Keratella quadrata quadrata* CARLIN, *Polyarthra vulgaris* CARLIN (abundant).

*Cladocera*: *Ceriodaphnia pulchella* SARS, *Chydorus sphaericus* O. F. M., *Moina* cf. *micrura* KURZ, *Scapholeberis mucronata* O. F. M.

*Copepoda*: nauplii (abundant), copepodits (abundant), *Cyclops* *Acanthocyclops vernalis* FISCHER.

The composition of the water was August 13th, 1951 as follows:

	Temperature (Centigrades)	pH	Alkalinity (mlval)	Chlorides (p.p.m.)
Nový Stav	22	7,6	2,0	400
Lesník	22	7,5	2,4	—
Heřmanský	21	7,2	—	—

The water of the fishpond Nový Stav belongs also to the oligohaline brackish waters (100—1000 mg Cl<sup>1</sup> pro liter, REDEKE, 1934). I think that the amount of chlorides in the other two ponds is slightly less than that of the pond Nový Stav. The salinity of these ponds is caused by the carboniferous sedimentary rocks in the bottom. The rotifers *Hexarthra fennica* LEVANDER and *Brachionus plicatilis* O. F. MÜLLER as well as the diatom *Bacillaria paradoxa* GMELIN are well-known characteristic forms and indicators for brackish waters. The other species which I have found have to be considered as euryhaline freshwater species, as stated by REMANE (1934) e.g. for *Keratella cochlearis* (= *K. stipitata*), *Keratella quadrata* and *Polyarthra trigla* (= probably *P. vulgaris*), already.

There are also in Czechoslovakia three districts with brackish waters, in which true brackish water living species are now known: The vicinity of the town Lednice (southern Moravia), Soos at the spa Františkovy Lázně (western Bohemia) and the northeastern vicinity of Moravská Ostrava, as just recorded.

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## EXPLANATIONS TO THE FIGURE ON P. 64

*Hexarthra fennica* LEVANDER. — Fig. 1. Frontal view with the ventral arm in foreground and the dorsal arm in background. — Fig. 2. Lateral view, the ventral arm on the left. Specimen with an egg. — Fig. 3. A ventral arm. — Fig. 4. A ventrolateral arm. — Fig. 5. A dorsolateral arm. — Fig. 6. Another ventral arm. — The figures 1, 3—6 are drawn in the same magnification. Original according to preserved specimens from silesian ponds.

# The production of organic matter by the phytoplankton in a danish lake receiving extraordinarily great amounts of nutrient salts

by

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Søllerød Sø, some 7 or 8 miles north of Copenhagen, which is about 15 ha in extent and up to about 7 m in depth, receives extraordinarily large quantities of purified sewage in proportion to its size. Investigations on the biological effects hereby have been started by Professor K. Erik Jensen, the chemist, C.V. Otterstrøm, M. Sc., fishery biologist, and the author of the present article. The results obtained will be published elsewhere. The present paper is intended only to give a short account of the production of matter by the phytoplankton. Knud Andersen, M. Sc., assisted in these investigations.

The investigations of the production of matter were made by means of the so-called Gran method, i.e. suspension at different depths of bottles (transparent as well as black) containing water from the lake. The oxygen metabolism is by means of Winkler titrations followed in these bottles. On the basis of the oxygen metabolism in the bottles it is possible to calculate the photosynthesis and the respiration at the various depths. It is furthermore possible to calculate the total production of matter and the total loss of matter per surface unit. Further details about the method are found in STEEMANN NIELSEN 1951 Chapter Two. At the present experiments the bottles were suspended at the depths 0.25, 0.5, 1, 2, 3, 4, and 5 m. Care was taken that the water at the start of the experiments was not super-saturated with air.

Whereas such experiments generally are made to last for 24 hours, the duration of the present experiments during the summer months was made shorter. The bottles were suspended in the evening after

sunset and taken up again when the sun was at its meridian altitude the next day. Thus half of the photosynthesis during a whole day was measured. The reason why a shorter time of experiment was used was that the huge rate of photosynthesis in the bottles gave rise to so great a production of oxygen that air bubbles developed. At a shorter experimental period it was possible to reduce the development of air bubbles considerably — although it was not possible to prevent it completely. On the basis of the size of the air bubbles it was possible to estimate that the values for the production of matter measured close to the surface were about 25 per cent. too low. We did not, however, correct for the oxygen in the air bubbles, in the first place because these appeared only in the bottles suspended at the depths at the nearest distance from the surface, in the second place because the error was estimated to be without greater importance for the problem investigated.

The experiments were made twice a month during a year (December 1943—November 1944), the ice in the lake during two winter months, however, preventing any investigations. The experiments were made in the middle of the lake, where the depth is about 7 m. The productive layer proved to be very thin, during the summer months only 1—2 m thick. This was due to the extremely large quantity of plankton, which absorbs the light. In March the productive layer was about 3 m thick. As the productive layer was so extraordinarily thin, surface water was used in all experiments. Plankton countings showed a rather even distribution of the plankton in the uppermost metres.

Green algae were completely dominant during the summer time. Blue-green algae, which in other years give rise to water-bloom in Søllerød Sø, did not appear in 1944. Besides green algae diatoms and flagellates occurred in winter and in the spring. The lake is typically alkaline. In the height of summer pH in the surface reached a value of 10.4. In winter and spring pH was about 8. The titration alkalinity in the surface varied between 4.5 mval./l in the spring and 2.6 mval./l in the height of summer. There were always extraordinarily large quantities of nutrient salts. The minimum value for phosphate in the surface thus was 200 mg  $P_2O_5/m^3$  (the middle of August). Iron perhaps occurs as a minimum substance in the height of summer. At any rate it is not possible at this time to demonstrate the presence of ferric ions.

Fig. 1 shows the actual photosynthesis (gross production) calculated as carbohydrate per sq. m surface per day. It is seen that the highest value — nearly 10 g glucose per sq. m and per day — was found in July. A gross production of 1300 g glucose was found for the whole year.



As appears from fig. 1 there are no statements for August. The series at the beginning of this month was lost. The next series was started on August 17 after sunset and was concluded the next day when the sun was at its meridian altitude. The experiments, however, showed no — or practically no — photosynthesis. Was there no photosynthesis in the lake? Measurements of oxygen made at the same time showed a saturation of 221 per cent. at the surface. Such an intense supersaturation can only occur in the case of a constant intense photosynthesis causing a great production of oxygen. Thus the photosynthesis cannot have been quite insignificant during daytime on August 17.

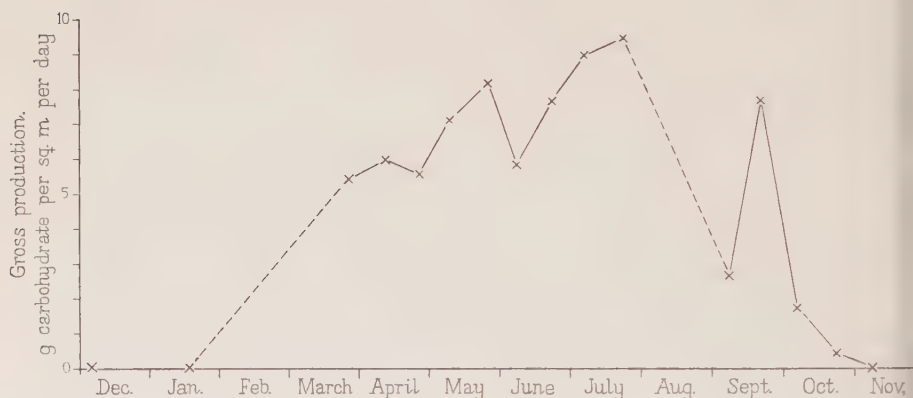


Fig. 1.  
Photosynthesis.

Unfortunately pH was not determined in the water used for the experiments of metabolism. At noon the following day pH in the surface, however, was 10.2 and presumably pH will increase somewhat during the day, falling during the night because of absorption of  $\text{CO}_2$  from the air and by admixture of water from somewhat deeper layers. To all appearance pH at the start of the experiment in the evening of August 17 thus was more than 10.2. As the limit of the tolerance of aquatic plants to hydroxyl ions will normally be somewhere between the pH values 10 and 11 (see STEEMANN NIELSEN 1947) there is nothing curious in the fact that it was practically impossible to demonstrate any photosynthesis in the surface water.

It would, however, be wrong to conclude from the missing photosynthesis in the experiment that no photosynthesis took place in the surface water of the lake during the same period. During the night

there will be an absorption of  $\text{CO}_2$  from the atmosphere through which the pH value at the surface will be reduced. Simultaneously because of the cooling an admixture to the surface of slightly deeper layers of water, in which pH had not reached so high a value during the day that the plankton algae had been injured, will take place. This admixture will cause partly a renewed supply of living plankton algae to the surface layer, partly a reduction of pH. Therefore photosynthesis will start again in the surface layer in the morning. The photosynthesis will not stop here till some time in the day when pH has increased to the value critical to the plankton algae.

At the following investigations in the lake on September 7—8 the situation was completely different as the summer stagnation had ceased. The deeper water masses of the lake which in the height of summer were oxygen-free and contained sulphuretted hydrogen had been mixed with the water masses of the surface. The consequence was that the amount of oxygen at the surface had been reduced to 21 per cent and pH to 9.4.

According to MÜLLER 1948, p. 90, the daily real photosynthesis (net production) per sq. m in a growth of well-manured barley (*Hordeum distichum nutans* f. *kenia*) is a good 40 g dry matter in June (Denmark). In Søllerød Sø only about 25—30 per cent. of this is reached in summer, even if it is considered that the determinations of the photosynthesis immediately below the surface are 25 per cent. too low because of the disengagement of air bubbles described above. The lower production per surface unit in Søllerød Sø indicates a lower utilization of light by the plankton algae than by the plants in a field of barley. It must be mentioned that other factors — first of all enzymatic ones — are also involved in the photosynthesis. Lack of e.g. iron in the surface water of the lake may very well have influenced the production of certain enzymes necessary in photosynthesis.

The question, however, arises whether it is possible at all in the case of a lake of the same type as Søllerød Sø and with its site yearly to produce very much more organic matter than shown in the present investigation. I think the question must be answered in the negative as the carbon dioxide metabolism will not allow of any materially greater photosynthesis in a lake of the present type.

Fig. 2 shows a curve of the total carbon dioxide in the surface water of Søllerød Sø. The figures are calculated from BUCH 1945 on the basis of titration alkalinity, pH, and temperature. It has been taken for granted that no other weak acids than carbon dioxide were present. This view presumably is not absolutely correct. To all appearance, however, such weak acids have not caused any material deviation.

The curve in fig. 2 clearly shows that the total carbon dioxide

varies greatly according to season. When the production set in in the spring, about 4.5 mmol CO<sub>2</sub> total/l were found in the surface. During the spring and summer this value decreased steadily to about one third. The cause of this decrease was the consumption of CO<sub>2</sub> for the photosynthesis by the plankton algae.

According to fig. 1 the gross production during the two summer months June and July was on the average 7.9 g glucose per day and per sq. m surface. If the surface layer is put at a thickness of 3 m, the respiration in this layer of water corresponded to 3.3 g glucose per day and per sq. m. The surplus production in this layer thus was 4.6 g glucose per day and per sq. m surface, corresponding to a consumption of 6.7 g CO<sub>2</sub>. During the two months there was thus — the photosynthetic quotient  $\frac{O_2}{CO_2}$  being put at 1.0<sup>1)</sup>. — a consumption

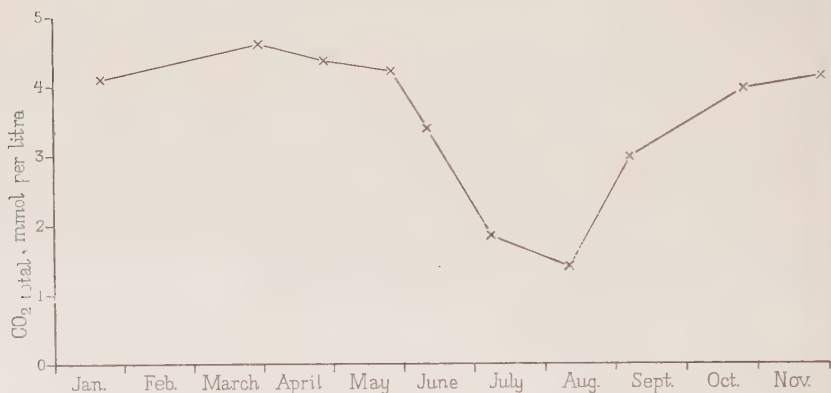


Fig. 2.

Total carbon dioxide in the surface water.

in the surface layer 0—3 m of 400 g CO<sub>2</sub> per sq. m. Furthermore a large quantity of CO<sub>2</sub> was removed from the surface layer because of precipitation of CaCO<sub>3</sub> — a secondary effect of the photosynthesis of the algae. According to the determinations of Ca there were 70 mg Ca/l about June 1, and 35 mg/l about August 1. From 3 cu. m (the surface water below 1 sq. m) there was thus a precipitation of 115 g CO<sub>2</sub> in the form of CaCO<sub>3</sub>.

Thus, with the 400 g consumed direct by the algae, a total of 515 g CO<sub>2</sub> per sq. m was removed. As the quantity of CO<sub>2</sub> total according

<sup>1)</sup> If the photosynthetic quotient is put at 1.1 — a possibly more correct value — this does not alter the calculations particularly.

to fig. 2 had dropped from 174 g CO<sub>2</sub> per cu. m to 68 g during the same period, the reduction in the uppermost 3 m was in all 318 g per sq. m surface. This shows that about 200 g CO<sub>2</sub> per sq. m must have been supplied to this surface layer from somewhere else during the same period. Part of this CO<sub>2</sub> was probably supplied by mixing with the water masses immediately below the surface layer proper, as at a depth of 4 m — but not at 5 m — it was possible to demonstrate a distinct increase in temperature during June—July. At a depth of 4 m 12.4° C. was measured on June 8, 15.3° C. on July 6, and 17.8° C. on July 22.

If the water masses had been completely mixed right down to a depth of 4 m, but no farther, and if the respiration at a depth of 4 m had been the same as in the surface, only about 125 g CO<sub>2</sub> per sq. m surface should have been added from outside during the period June 1—August 1. Therefore the amount actually supplied from outside — i.e. from the atmosphere — must be supposed to be between 125 and 200 g CO<sub>2</sub> per sq. m surface. Per month thus between 60 and 100 g CO<sub>2</sub> was absorbed. As Søllerød Sø is about 15 ha, a total of between 10 and 15 tons CO<sub>2</sub> was absorbed from the air during a summer month, which corresponds to the total amount of CO<sub>2</sub> in a layer of air of a height between 100 and 150 m.

As shown above, it was not until August that pH became the absolutely decisive limiting factor to the production of plankton. If the production of matter before that time had been greater, the pH-limit would have been reached previously. The CO<sub>2</sub> absorption from the atmosphere would not have been increased, at any rate not materially. Thus it is in reality the CO<sub>2</sub> absorption which decides the size of plankton production in this lake. This shows that in our latitudes we shall probably not find a lake with a much greater production than Søllerød Sø. If so, the alkalinity of the water must either be abnormally high, or the surface layer must constantly be renewed by admixture of water from somewhere else.

The amount of plankton measured per volume of water is exceedingly great in summer in Søllerød Sø. The photosynthesis in the surface measured per volume is exceedingly great, too. Measured per surface unit the photosynthesis is indeed great, but not exceedingly great. This is due to the slight thickness of the productive layer in summer — about 1.5 m. It should be mentioned that in the sea — with a productive layer of about 18 m — it is possible to find a production of nearly the same magnitude as that in Søllerød Sø (STEEMANN NIELSEN 1954, St. 167, Fig. 3).



## SUMMARY

The production of organic matter by phytoplankton in Søllerød Sø, which receives large amounts of purified sewage, has been determined at 1300 g glucose per sq. m and year. A maximum of 9.5 g per sq. m is reached per day. It is shown that the yearly production in a lake of this type presumably cannot be considerably greater as through the consumption of carbon dioxide pH will increase to such a degree that this factor becomes injurious to the plankton algae. The uptake of  $\text{CO}_2$  from the atmosphere whereby pH is lowered thus is the real limiting factor for the production of organic matter in the lake. During the height of summer between 60 and 100 g  $\text{CO}_2$  is absorbed from the atmosphere per sq. m surface per month.

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# Occurrence of *Dinobryon crenulatum* Wm. et G. S. West in some Danish ponds and remarks on its morphology, cyst formation, and ecology.

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For three years, 1946, 1947, and 1948, I have, about once every fortnight, taken samples with a view to plankton investigations from the surface water in four of the Hellebæk ponds, Bøgholm Sø, Bondedam, Kobberdam and Sortesø, situated N.W. of Elsinore in northeastern Sealand. These ponds are small forest pools, the first three not over 3 m deep, Sortesø with a maximum depth of 6 m. Bøgholm Sø, Bondedam, and Kobberdam are brownish-watered, neutral or slightly alkaline pools, fairly rich in phytoplankton, while Sortesø is more dark-watered, slightly acid and much poorer in phytoplankton than the others. A more detailed description of the appearance and chemistry of the ponds, and of the methods of sampling and taking counts will appear later.

Bøgholm Sø, Bondedam, and Kobberdam contain a fairly rich population of *Dinobryon* species, particularly in the spring. I have found seven species:

*Dinobryon bavaricum* IMHOF

*Dinobryon crenulatum* WM. et G. S. WEST

*Dinobryon cylindricum* IMHOF var. *alpinum* BACHM.

*Dinobryon divergens* IMHOF var. *Schauinslandii* BRUNNTH.

*Dinobryon sertularia* EHRB.

*Dinobryon sociale* EHRB.

*Dinobryon suecicum* LEMM. var. *longispinum* LEMM.

In Sortesø I have never found other species than *D. divergens*. It occurs here as a late summer form, occasionally with very considerable maxima in August—September. The greatest maximum of all *Dinobryon divergens* maxima observed occurred in Sortesø.

Since the description of *Dinobryon crenulatum* by W.M. and G. S. WEST from the English lake district (1909 pp. 323—325) is incomplete, I will give a closer account of it and its occurrence in the Hellebæk ponds.

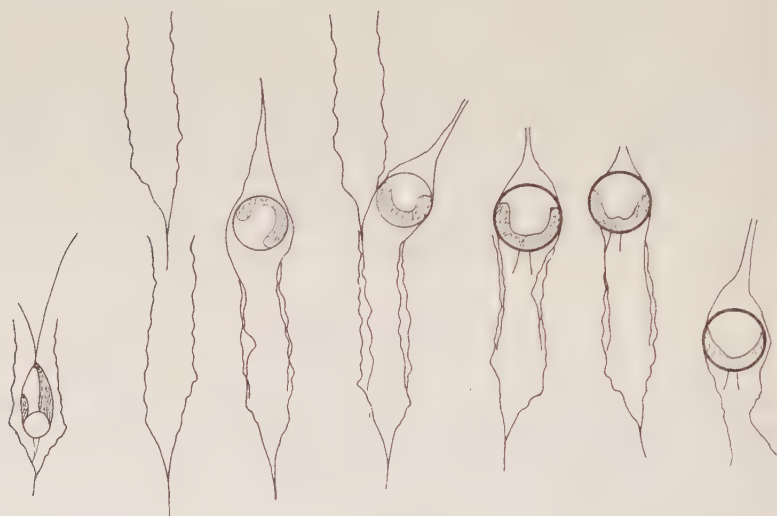


fig. 1

fig. 2

fig. 3

fig. 4

fig. 5

fig. 6

fig. 7



fig. 8

fig. 9

Fig. 1. Solitary individual of *Dinobryon crenulatum*.

Fig. 2. Colony of 2 individuals.

Fig. 3-6. Various stages of cyst and envelope.

Fig. 7. Envelope with cyst.

Fig. 8-9. Anomalous cyst formation.

According to W.M. and G. S. WEST *Dinobryon crenulatum* differs from all the known species of *Dinobryon* in its completely crenulate wall from base to apex. The WESTS do not mention the cell content, they have not observed cysts and they have only seen solitary individuals. The appearance of the specimens found in the Hellebæk ponds is shown in figs. 1—9. The completely undulate wall is seen. The undulation is most marked at the transition between the base and the upper part of the receptacle. The latter is subcylindrical, tapering

somewhat towards the slightly dilated mouth. The base of the receptacle is cut off obliquely in front, at the posterior end it is produced into a spine. Length of receptacle without spine 30—50  $\mu$ , breadth at the broadest part 8—10  $\mu$ , length of the spine 3—8  $\mu$ . The receptacles of the Hellebæk individuals vary more in size and form than the individuals described by the WESTS. They may be longer and more slender with a long spine (fig. 2), or shorter and broader with a short spine (fig. 1). The latter form especially occurs in the summer maxima of July, and it is this form which corresponds most closely to the individuals described by the WESTS. In the Hellebæk ponds the cells of *Dinobryon crenulatum* are most frequently solitary, though they appear, by no means rarely, in small colonies of two or three cells fastened together in the same way as in all other *Dinobryon* species. The protoplast is oval, broadly rounded at the posterior end, tapering somewhat obliquely in front and attached to the base of the receptacle in the usual way by a plasma stalk. It lies well withdrawn into the receptacle, extending some way into the base of it. There are two parietal chromatophores, a larger anterior one with a somewhat obliquely produced point, and a smaller posterior one. There is one apical eyespot. The chromatophores are greenish brown. The posterior part of the protoplast is taken up by a large leucosin grain. Two cilia issue from the protoplast, a longer one projecting by half its length outside the receptacle, and a shorter one projecting slightly outside the receptacle.

Cyst formation occurs nearly every spring in the Hellebæk ponds. In July, no cyst formation has been observed. The cyst (figs. 5—7) is usually spherical, about 10  $\mu$  in diameter, with a collar 3—5  $\mu$  long, turned towards the receptacle. The collar is wider at the mouth than at the base. In the spring of 1951 all the cysts were more short-collared than previously observed, the collar not being much longer than that of the cysts of *Dinobryon divergens* which at the same time had a large maximum with a rich formation of cysts. As usual the cyst formation takes place a little way outside the receptacle, and the cyst is surrounded by an envelope of a very peculiar appearance (figs. 3—7). At the beginning of the cyst formation, before the wall of the cyst has become silicified, the envelope looks almost like a copy of the receptacle itself, with its mouth inserted in the latter, and extending into the receptacle almost as far as the transition between base and upper part (fig. 3). That part of the envelope which protudes outside the receptacle is, however, a little less undulate and somewhat expanded where the cyst is attached. The undulations inside the receptacle approximately follow the wall of the receptacle, except in one place where the envelope bulges towards the interior of the receptacle (figs. 3, 5). Gradually as the cyst grows older, the enve-



lope changes its appearance, it becomes narrower and more smooth, and an opening is seen in the anterior end which is now long and narrow (fig. 4). This part of the envelope gradually shrinks more and more (fig. 5) and in the end the envelope may become a short smooth-walled cone with a small anterior opening (fig. 6). Twice, in April 1951 and in May 1951, I found a rather divergent cyst formation (figs. 8, 9). In these two individuals the envelope had a more generally rounded form differing entirely from that of the other cysts, and the cysts were oval. In one instance the cyst formation had taken place quite abnormally inside the receptacle (fig. 9). The material of these cysts are too scarce to allow any conclusions on the cause of this deviating cyst formation. It might be a variety of *Dinobryon crenulatum* or it might be another kind of reproduction.

When I first observed the formation of the cyst in *Dinobryon crenulatum* I thought I was here concerned with an isogametic sexual reproduction believing the envelope of the cyst to be an individual which had crept into another individual, with an ensuing fusion of the protoplasts, the formation of a silicious wall round the zygote, and a succeeding reduction of the envelope of the individual which had entered. I have, however, never been able to observe anything to indicate that a zygote formation has taken place. The position of the cyst and the envelope and the orientation of the cyst, with the axis running through the collar in the longitudinal direction of the receptacle correspond exactly to the position and orientation in other *Dinobryon* species. By means of carmine acetic acid I have found that there is only one nucleus in the cysts, but this of course does not exclude the possibility that the cyst is a zygote in which the two nuclei have already fused. As neither envelope nor receptacle have shown cellulose reaction with the usual tests I have neither in this way been able to find out if the cysts are of asexual or sexual origin. If the latter is the case, the above mentioned diverging cysts might be the result of an asexual reproduction. SKUJA (1950) has described the first authentic case of zygote formation in the genus *Dinobryon*, namely by *Dinobryon Borgei* LEMM., but here the gametes merely place themselves mouth to mouth, adhering together by means of the long cilia, whereupon the protoplasts issue and become fused. The cyst-like zygote is orientated athwart the longitudinal axis of the receptacle, while the ordinary cysts have the collar in the longitudinal direction of the receptacles.

PASCHER (1913) does not mention *Dinobryon crenulatum*, whereas under the section *Dinobryopsis* there is a reference to a new species: *Dinobryon acuminatum* RUTTNER, which seems to be closely related to or perhaps identical with *Dinobryon crenulatum*. It is, however, less undulate and somewhat slenderer. The cyst is identical with that of

*Dinobryon crenulatum*. The cyst envelope resembles the final stage of the envelope of *Dinobryon crenulatum*.

Table 1.

Mean temperature of the distribution of *Dinobryon crenulatum* and *Dinobryon divergens* in 1946, 1947, and 1948. Samples have been collected every fortnight, but only the dates on which the organisms have been found are given in Table.

Means that the species concerned were found in samples from the date in question, but not on the counting date. The figures denote number of cells per ml.

*Dinobryon crenulatum*

Year	1946										
Dates	26/4	8/5	22/5	6/6	20/6	7/7	19/7	14/8	31/8	17/9	6/10
Mean temp. of the air	13.3°	10.5°	13.3°	14.9°	13.3°	17.7°	21.0°	16.4°	16.3°	15.3°	8.7°
Bøgholm							145	+			
Bondedam	45					+					
Kobberdam	50	+									
Sortesø											

*Dinobryon divergens*

Bøgholm	10	210	20	25			200	+	+		
Bondedam	45	350	25	+							
Kobberdam		160	25		5		10	20			
Sortesø	+	+							230	70	5

*Dinobryon crenulatum*

Year	1947			1948									
Dates	29/4	14/5	31/5	30/3	14/4	29/4	15/5	17/6	7/7	27/7	14/8	28/8	9/9
Mean temp. of the air	8°	18.8°	23.1°	8.3°	8.9°	8.1°	16.1°	13.6°	15.8°	21.3°	19.2°	15.6°	18.1°
Water temp.	11.5°	16°	24°	10°	11°	13.5°	19°	20°	19.5°	25°	22°	20°	19.5°
Bøgholm		30			+								
Bondedam		+			130	45	+		20	10			
Kobberdam	5				200	10				15			
Sortesø													

*Dinobryon divergens*

Bøgholm		215	5	335	325		35						
Bondedam	445	1670	190	55	930	530		150					
Kobberdam	915	220			+	+							
Sortesø									2580	600	235	60	

KRIEGER (1930) only mentions the forms belonging to *Eudinobryon* and as *Dinobryon crenulatum*, according to WM. and G. S. WEST's description, must be classed among the group of *Dinobryopsis* that does not form colonies, he has no reason to include it in his monograph. Since it has now turned out that *Dinobryon crenulatum* may form colonies it must in future be classed with *Eudinobryon*.

HUBER-PESTALOZZI (1941) does not mention *Dinobryon crenulatum*.

As previously stated, *Dinobryon crenulatum* was found in Bøgholm Sø, Bondedam, and Kobberdam, but never in Sortesø. Its occurrence in the years 1946—1948 as well as that of *Dinobryon divergens* will appear from the survey in table 1 and from fig. 10—13.

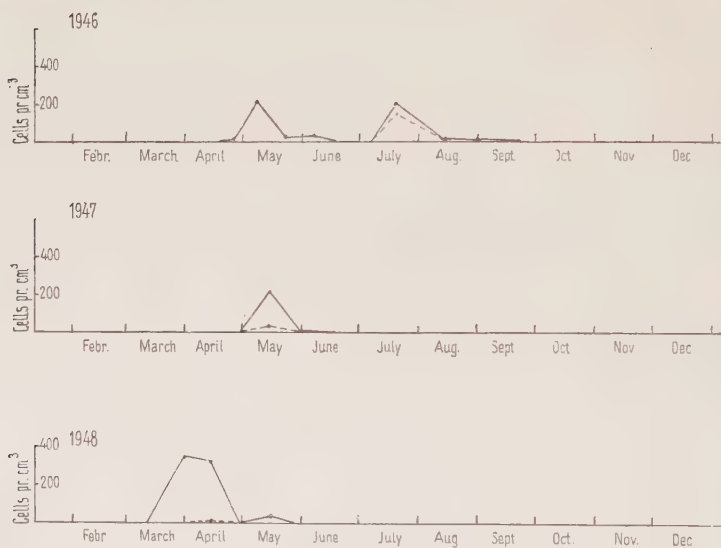


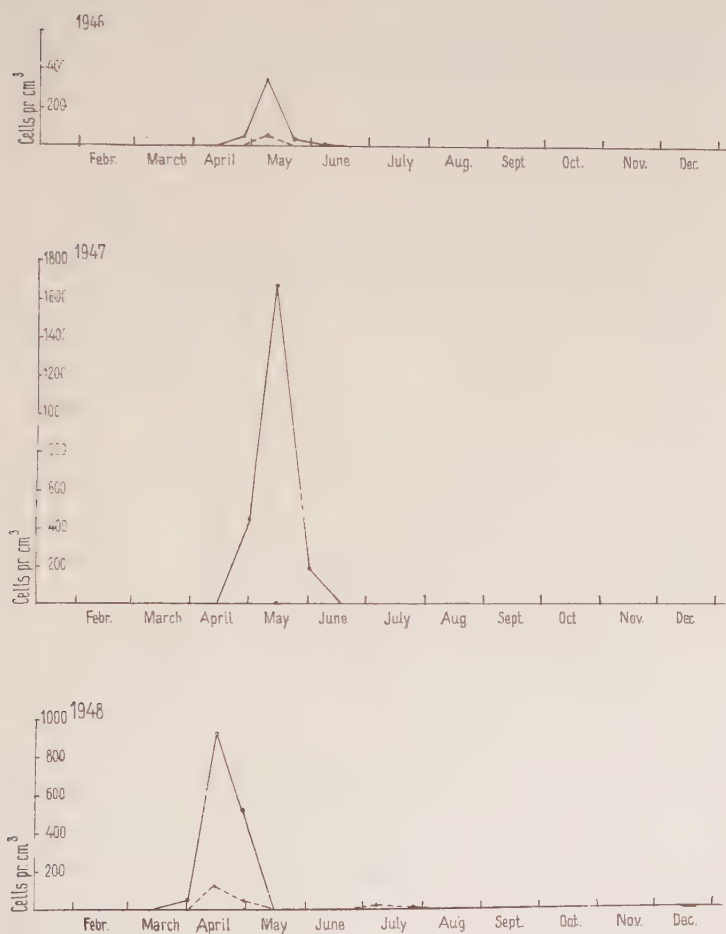
Fig. 10. Distribution of *Dinobryon crenulatum*---- and *Dinobryon divergens* — in Bøgholm Sø 1946, 47 and 48.

The table also shows the temperatures at the surface of the water measured during the sampling. Unfortunately I have only these temperatures for 1947 and 1948, so I have also given the mean temperatures of the air for the three years. The differences between the water temperatures in the various ponds are so small that they disappear when the figures are rounded off. As a further illustration of the temperature conditions table 2 gives the monthly average temperatures for January—July.

Table 2.

The monthly average temperatures for January—July 1946—48.

	J	F	M	A	M	J	J
1946	0.3	0.9	1.8	8.7	13.0	14.6	19.5
1947	— 2.3	— 6.3	— 1.7	6.8	14.4	18.5	18.8
1948	1.2	0.5	4.4	9.3	12.8	16.7	18.1

Fig. 11. Distribution of *Dinobryon crenulatum* ---- and *Dinobryon divergens* — in Bondedam 1946, 47 and 48.

As will be seen from table 1, *Dinobryon crenulatum* appears in rather small numbers. Its maxima normally occur in the spring at



water temperatures of about  $11^{\circ}$ — $16^{\circ}$ ; on one occasion, in Bøgholm Sø in 1946, there is a more considerable summer maximum in July. In 1948 there are small maxima in July in Bondedam and Kobberdam. Hence other conditions being suitable, it will tolerate higher temperatures than spring temperatures. Cyst formation has never been observed during the summer maxima. The maxima are of rather short duration, but as the samples were taken at intervals of about a fortnight, it may of course very well be the case that the highest peaks of the maxima are not observed at all. Since it evidently does not thrive well at temperatures much below  $11^{\circ}$ , it appears when the large *Dinobryon cylindricum* maximum of the spring is decreasing. Often its maxima coincide with those of *Dinobryon*

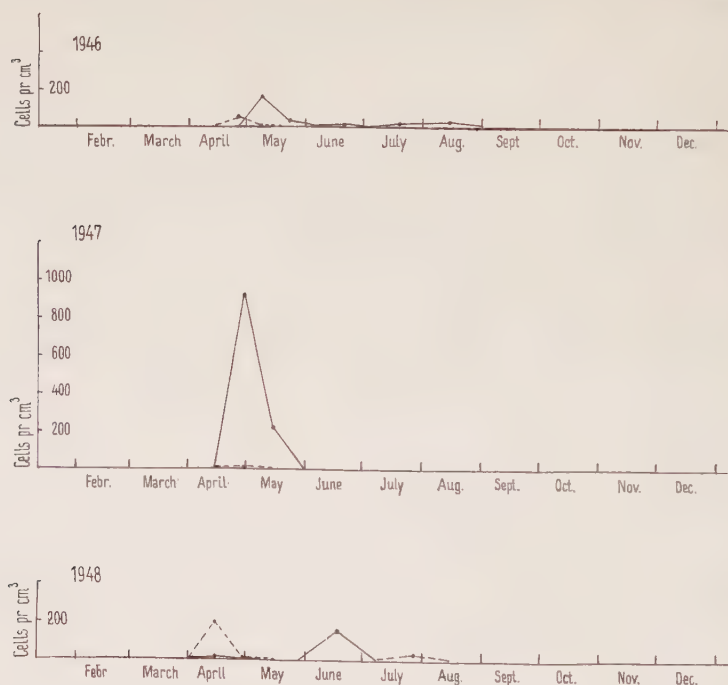


Fig. 12. Distribution of *Dinobryon crenulatum* --- and *Dinobryon divergens* — in Kobberdam 1946, 47 and 48.

*divergens*. That it does not require altogether the same conditions as *Dinobryon divergens* will be seen from the fact that in 1946, and especially in 1948, there were large August maxima of *Dinobryon divergens* in Sortesø, whereas no trace of *Dinobryon crenulatum* was ever found in this pool. Bondedam had its largest maximum of *Dinobryon divergens* in May 1947, the year when *Dinobryon crenu-*



Numero of samples	1	2	3	4	5	6	7	8	9
<b>Xanthophyceae</b>									
<i>Centritractus africanus</i> Frisch et Rich						+			+
<i>Gloeobotrys limneticus</i> Pasch.						55			+
<i>Ophiocytium capitatum</i> Wolle	+								+
<b>Tetrasporales</b>									
<i>Elakatothrix viridis</i> Printz	+					+			+
<i>Gemelliscystis neglecta</i> Teilings?		+					+		+
<i>Gloeocystis gigas</i> Lag.									+
" <i>planctonica</i> Lemm.	+						250cl		+
<i>Sphaerocystis Schroeteri</i> Chodat									+
<b>Volvocales</b>									
<i>Chlamydomonas</i> sp.		+	+	30	+			+	+
<i>Dysmorphococcus Fritschii</i>						80			
Undetermined Volvocales						40			

*latum* was rarely found here. On the other hand, Kobberdam had its largest population of *Dinobryon crenulatum* in the spring of 1948, at which time *Dinobryon divergens* was very rare. Thus it would seem that conditions which more particularly favour a development of *Dinobryon divergens* inhibit *Dinobryon crenulatum*, while conditions that particularly inhibit *Dinobryon divergens* may be favourable, though they are not always so, to *Dinobryon crenulatum*. The unusually cold spring in 1947 may have inhibited *Dinobryon crenulatum*, but have favoured *Dinobryon divergens*, perhaps by diminishing the competition from the organisms, which are more sensitive to low temperatures than *Dinobryon divergens*. The particularly mild spring in 1948 with the consequent early appearance of the maxima of *Dinobryon crenulatum* in Kobberdam and Bondedam may

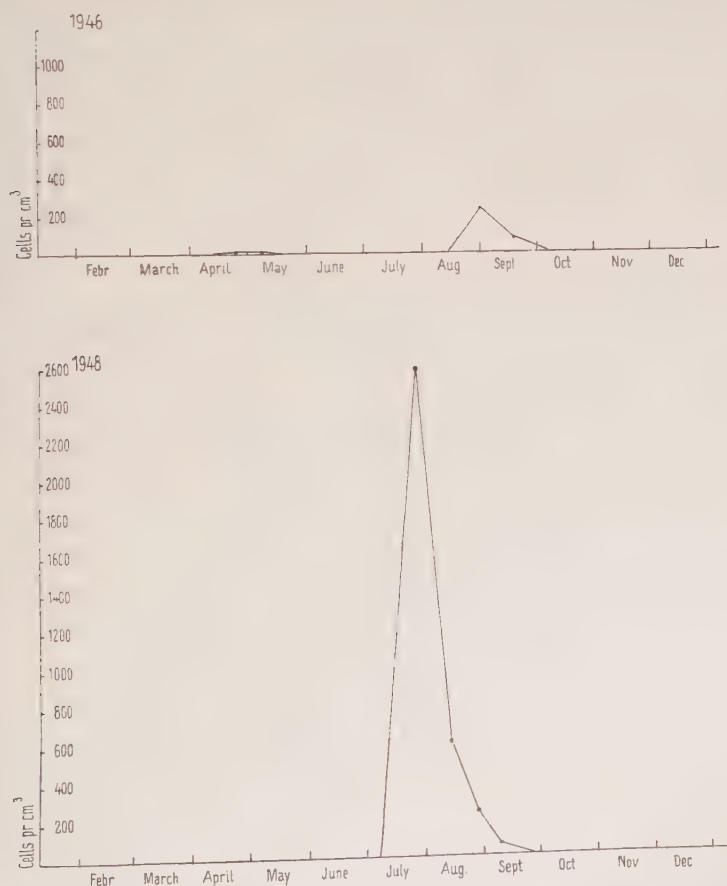


Fig. 13. Distribution of *Dinobryon divergens* in Sortesø 1946 and 48.



be the cause of the especially large maxima that spring. The extremely cold spring in 1947 was followed by an unusually warm and dry summer. The very shallow Bøgholm Sø was almost totally desiccated; the plankton was quite abnormal with few species and individuals even in 1948 and no *Dinobryon crenulatum* was found in July 1947 and 1948.

Some examples of the plankton communities in which *Dinobryon crenulatum* is found are given in table 3. The figures denote number of cells per cm<sup>3</sup> where it is not expressly stated that it is colonies, filaments, trichomes, or coenobia that have been counted. The numbers are only given for the more frequently occurring species among which I have somewhat arbitrarily included those that occur in a number of twenty and upwards per cm<sup>3</sup>. The more rare species are marked by +.

The plankton lists do not claim to be complete, the determinations being carried out on fixed material. Many small delicate flagellates were therefore not recognizable and are not listed. I have not been able to identify all species, some genera such as *Chlamydomonas* and *Cryptomonas*, are not dealt with at all, but undetermined species of more important taxonomic groups are listed in order to make it possible to count the number of species of these groups.

A survey of the three most frequent species of the plankton communities in which *Dinobryon crenulatum* occurs is given below; the numeros are the same as in table 3:

- Sample No. 1 *Melosira granulata* var. *angustissima*, *Dinobryon divergens* var. *Schauinnslandii*, *Ankistrodesmus convolutus* var. *minutus*.
- „ No. 2 *Ankistrodesmus falcatus* var. *setiformis* f. *brevis*, *Dinobryon divergens* var. *Schauinnslandii*, *Cyclotella stelligera*.
- „ No. 3 *Cryptomonas* sp., *Uroglena americana*, *Synura Petersenii*.
- „ No. 4 *Synura Petersenii*, *Synura sphagnicola*, *Synura spinosa*.
- „ No. 5 *Synura Petersenii*, *Synura spinosa*, *Synedra acus* var. *delicatissima*.
- „ No. 6 *Closterium gracile*, *Ankistrodesmus falcatus* var. *setiformis* f. *brevis*, *Chrysococcus porifer*.
- „ No. 7 *Ankistrodesmus falcatus* var. *setiformis* f. *brevis*, *Synedra acus*, *Cryptomonas* sp.
- „ No. 8 *Synedra acus* var. *delicatissima*, *Ankistrodesmus falcatus* var. *mirabilis* f. *dulcis*.
- „ No. 9 *Microcystis holsatica*, *Ankistrodesmus falcatus* var. *spirilliformis*, *Crucigenia tetrapedia*.

Table 4 gives a survey of the number of frequent species, i.e. 20 and upwards, per cm<sup>3</sup> of some important taxonomic groups, partly on the same dates as in table 3, partly on dates when *Dinobryon crenulatum* owing to temperature and date might be expected to be present, but was not observed.

Table 4.

Survey of number of frequent species (20 and upwards pr. cm<sup>3</sup>) of the most important taxonomic groups, and the total number of species observed. The numeros 1—9 are the same as in table 3, the numeros 10—18 are samples in which *Dinobryon crenulatum* according to date and temperature might be present, but was not found.

Localities	Bøgholm		Bondedam				Kobberdam		
Dates	19-7-46	14-5-47	8-5-46	14-4-48	29-4-48	7-7-48	26-4-46	14-4-48	27-7-48
Numero of samples	1	2	3	4	5	6	7	8	9
Myxophyceae	0	1	0	0	0	1	0	0	2
Euglenineae	0	0	2	0	1	3	1	0	1
Centrales	4	1	3	0	6	5	3	2	0
Pennales	0	0	3	4	4	2	1	1	2
Chrysophyceae	5	3	10	8	5	4	3	2	1
Chlorococcales	8	4	4	3	7	21	4	6	6
Desmidiaceae	0	0	0	0	0	1	0	0	3
Total number of species	55	52	70	47	68	106	52	51	92

Localities	Bøgholm			Bondedam			Kobberdam		
Dates	26-4-46	29-4-47	24-7-47	26-4-46	29-4-47	24-7-47	19-7-46	14-5-47	24-7-47
Numero of samples	10	11	12	13	14	15	16	17	18
Myxophyceae	0	0	0	0	0	1	3	0	1
Euglenineae	0	0	1	1	0	2	2	0	2
Centrales	0	1	0	0	0	3	1	1	0
Pennales	1	0	0	1	1	0	0	1	2
Chrysophyceae	2	2	0	4	5	1	1	3	1
Chlorococcales	2	0	1	5	1	13	14	2	2
Desmidiaceae	0	0	0	0	0	2	2	0	0
Total number of species	43	27	54	43	39	61	68	43	62

From table 3 and 4 and from the list of the three most frequent associates it will be seen that *Dinobryon crenulatum* occurs in associations of flagellates, diatoms and chlorococcales. Some of the most constant associates (NYGAARD 1949, p. 4) are *Cryptomonas* species, *Dinobryon* species, *Melosira ambigua*, *Synedra acus*, *Ankistrodesmus falcatus* var. *setiformis* f. *brevis*, *Crucigenia minima*, and *Scenedesmus setiferus*. There is a conspicuous difference in number of species between the samples containing *Dinobryon crenulatum* and the samples in which it, according to temperature and date, might be present, but is not found. The latter are much poorer in organisms with the exception of the samples Nos. 15 and 16. In these July samples there is a great development of *Aphanizomenon flos aquae*, whereas the July samples with *Dinobryon crenulatum* are almost without *Aphanizomenon flos aquae*. Thus conditions which favour *Aphanizomenon flos aquae* may inhibit *Dinobryon crenulatum*.

Table 5.

Water analyses. The analyses are made at the end of the months. The figures denote mg per litre.

	HCO <sub>3</sub> <sup>—</sup>	SO <sub>4</sub> <sup>—</sup>	Cl <sup>—</sup>	NO <sub>3</sub> <sup>—</sup>	PO <sub>4</sub> <sup>—</sup>	Ca <sup>++</sup>
Bøgholm April 1948	44	52	23	9	0	30
Bondedam April 1948	61	51	24	8.3	0	32
Kobberdam April 1948	53	45	25	Trace	0	30
Bondedam July 1948	73	37	26	4.5	0	31
Kobberdam July 1948	61	43	26	16	0	32

	Mg <sup>++</sup>	NH <sub>4</sub> <sup>+</sup>	Na <sup>+</sup> + K <sup>+</sup> calculated as Na	O <sub>2</sub> consump- tion	Si O <sub>2</sub>
Bøgholm April 1948	4.8	0.2	16	28.8	3.6
Bondedam April 1948	5.5	0.15	19	20.0	4.6
Kobberdam April 1948	3.7	Trace	17	18.8	2.4
Bondedam July 1948	4.0	0.15	21	17.2	1.4
Kobberdam July 1948	4.1	0.10	22	18.4	3.2

Some data of the ecology of *Dinobryon crenulatum* are given in table 5. The analyses are from 1948. No analyses were made in 1946 and 1947. Only analyses from the months and localities with *Dinobryon crenulatum* are given.

Some measurements of the hydrogen-ion concentration showed the following values of pH; Bøgholm Sø 27.-7.-48: 7, Bondedam 29.-7.-48: 7.4, Kobberdam 29.-7.-48: 7.3. As mentioned above all the ponds are brownish-watered.

Judging from the occurrence of *Dinobryon crenulatum* in the Hellebæk ponds it must be said that *Dinobryon crenulatum* is a meso- to polythermic (NYGAARD 1949, p. 4) spring and early summer form with a eutrophic tendency.

Mr. GUNNAR NYGAARD, M.Sc., whom I thank for assisting me in determining *Dinobryon crenulatum* and for reading this paper, has recently shown me some drawings of *Dinobryon crenulatum* (fig. 14) found by him on March 6th 1931 in Madum Sø, a lake, 8 m deep, situated in North East Jutland. The hydrochemical data of this lake on the date in question are (NYGAARD 1938, p. 685): pH 4.9, 2.4 mg/l CaO, consumption of  $\text{KMnO}_4$ , 6.3 mg/l, 0.01 mg/l iron, 0 mg/l  $\text{PO}_4\text{—P}$ , 0.15 mg l  $\text{NH}_3\text{—N}$ , 0.11 mg l  $\text{NO}_3\text{—N}$ . The lake was covered with ice. Thus it is evident that *Dinobryon crenulatum* may tolerate non-calcarous, rather acid and extremely clear water, and very low temperatures, but as nothing is known about the amount of the alga and its seasonal variations in Madum Sø it is impossible to decide how well it is thriving in this lake.

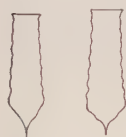


Fig. 14.

*Dinobryon crenulatum* from Madum Sø. 1000  $\times$ . Long. 32—34  $\mu$ , lat. max. 9—10  $\mu$ .

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# Some new diatoms from Blakeney Point (Norfolk)

by

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In the course of researches on the microscopic algae of the salt-marshes at Blakeney Point, Norfolk, England, new species of diatoms have been found. Some of these are described below; others will be described later, together with a new method for cleaning soil diatoms.

The area examined (see OLIVER and SALISBURY (1913)) can be roughly divided into 4 regions:

1. Lower marginal zone of the marsh (Station 5).
2. Higher zone of the marsh (Station 1, 2, 4).
3. Upper zone of the marsh (Station 6, 7, 8).
4. Spray zone (Station 3).

The various stations are shown in the map (pl. II).

## DESCRIPTION of New Species and Varieties

Type-specimens of all the following are lodged in the herbarium of the British Museum (Natural History) London.

1. *Eunotogramma rectum* SALAH nov. spec. (pl. I, fig. 1—8)

*Frustulis* simplicibus, a cinguli facie visis subrectangularibus; *valvis* 8—22  $\mu$  longis, 2—3  $\mu$  latis, linearibus, 2—7 pseudoseptis ad quae fortiter sunt constrictae; area valvae centrali marginibus parallelis, aliquando concavis; superficie hyalina; *apicibus* acutis vel rostrato capitatis.

This species is distinguished from all the others by its straight valves. *E. dubium*, recently described by HUSTEDT (1939, p. 593,

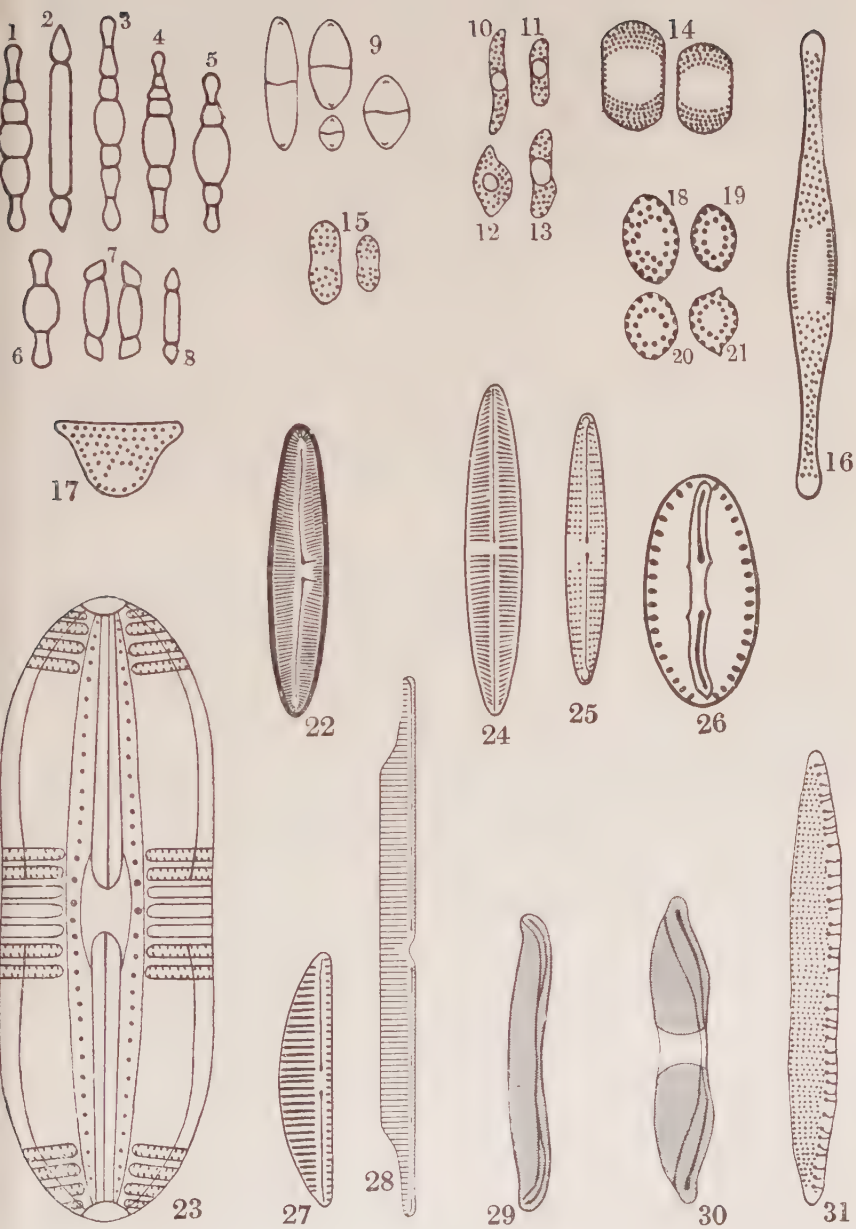


fig. 8—10) from the North German Coast, is the only other species with hyaline valves, but *E. rectum* differs in the absence of curvature, in the large numbers of pseudosepta found in some specimens (only 2—4 in *E. dubium*), and in the strong constriction at the pseudosepta. Although there is a wide range of variation in the shape of the valve, there are no well-defined varieties as the different types grade into one another and occur in the same habitat.

*E. rectum* is one of the commonest diatoms on the marsh, being found all the year round in the lower marginal zone, where it becomes very abundant during spring and autumn. It has also been met with elsewhere, especially near the creek and its tributaries. The wide range of level and the region of greatest abundance show that the species should be classed as mesohalobous and euryhaline.

2. *Anaulus uniseptatus* SALAH nov. spec. (pl. I, fig. 9)

*Valvis* late vel anguste lanceolatis, polis obtusis rotundatis, axe apicali 5—19  $\mu$ , transapicali 3.5—5  $\mu$ ; ad polos habentibus processus parvos ocellatos paene semicirculos leviterque super superficiem in alternis valvae lateribus sublatis; superficie valvae septo transverso succurvo dimidiata.

This *Anaulus* is peculiar in possessing a single transverse septum, whereas there are two or more in the other species of the genus. It is frequent in the lower marginal zone throughout the year. Its restriction to the neap-tide zone of the marsh, where the salinity approximates to that of the sea, shows that it should be classed as euhalobous.

3. *Plagiogramma sigmoideum* SALAH nov. spec. (pl. I, fig. 10—13)

*Valvis* brevibus, leviter in medio convexis, polis obtusis plerumque sigmatis modo curvis, 6—12  $\mu$  longis, 3—4  $\mu$  latis; dimidiatis spatio hyalino plerumque circulari subovato, valvae marginem attingente spatiumque linquente; punctis subtilibus per superficiei partem alteram sparsis; ad apices spatiis hyalines angustissimis.

This curious species of *Plagiogramma* is characterised by its delicate structure, as well as by the short valves with the extremities slightly bent in opposite directions. It shows certain similarities to *P. leve* (Greg.) Ralfs (PRITCHARD, 1861, p. 775 fig. 637) in which the valves have a similar central hyaline space, but my species is distinguished by its sigmoid shape and the irregular disposition of the puncta over the surface.

*P. sigmoideum* is very common on the spit and is not restricted to any one season. It shows a wide vertical range, although in general more abundant in the lower marginal zone than in the higher regions of the marsh. It is to be classed mesohalobous and euryhaline.

4. *Plagiogramma parallelum* SALAH nov. spec. (pl. I, fig. 14)

*Valvis* brevibus, lateribus parallelis, apicibus latis rotundatis; longis 8—10  $\mu$ , 5—6  $\mu$  latis; *area centrali* lata, plerumque dimidia valvae parte maiore; *striis* c. 16—18 in 10  $\mu$ , subtiliter punctatis, in ordinibus curvis moniliformibus dispositis; *pseudoraphe* nulla; *area terminali* indistincta.

This differs from the other species of the genus in its peculiar valves, which are short and broad with parallel sides and blunt extremities, and have a broad central area.

*P. parallelum* occurs sporadically and never in any considerable numbers in collections from near mean high water of neap-tides. Position in the halobion system; euhalobous?

5. *Plagiogramma minimum* SALAH nov. spec. (pl. I, fig. 15).

Species plerumque parvula cuius singula 6—14  $\mu$  longa, 2.5—3  $\mu$  lata; *valvus* lanceolatis vel oblongolanceolatis, leviter in medio constrictis, apicibus subrotundatis, septo Augusto transverso hyalino dimidiatis et per duo segmenta ita facta punctis irregulariter dispositis, nonnunquam sparsis; *area hyalina mediana* nulla, *pseudoraphe* nulla.

This species shows some resemblance to *P. Vanheurckii* Grunow (in VAN HEURCK, 1880—5, pl. 36, fig. 4), but differs from it in the absence of the central robust pseudoseptum, of terminal pseudonodules, and of an indistinct pseudoraphe, as well as in the details of the markings.

*P. minimum* is common and widely distributed throughout the marsh, being found at different levels and at all times of the year, although with a preference for the lower marginal zone. It is always found associated with *P. sigmoideum* SALAH, and is to be classed ecologically as mesohalobous and euryhaline.

6. *Plagiogramma brockamnni* HUSTEDT, var. *elongatum* SALAH nov. var. (pl. I, fig. 16)

*Valvis* anguste ellipticis, leviter in medio convexis, ad apices versus rotundatos productos attenuatis; 30—40  $\mu$  longis, 3—4  $\mu$  latis; *area centrali* elliptica; *punctis* irregulariter dispositis, aliquando sparsis; pseudonodulis terminalibus hyalinis subvatis; *pseudoraphe* nulla.

The variety differs from the type (cf. HUSTEDT 1939, p. 595, fig. 11, 12) in the shape of the valve, which is longer with produced apices, and in the irregular arrangement of the puncta.

No intermediate forms connecting the variety with the species have been observed, both occur in gatherings from the lower mar-



ginal zone of the marsh, but the type is found in greater numbers than the variety.

7. *Campylosira alexandrica* SALAH nov. spec. (pl. I, fig. 14).

*Valvis* semicirculatis, 8—12  $\mu$  longis (raro longioribus), 5.5—6.5  $\mu$  latis; margine ventrali recto, dorsali maxime convexo; apicibus plerumque productis; superficie valvae punctis rudibus 11 in 10  $\mu$  tecta, in medio distantioribus quam ea quae prope marginem sunt invenienda, aliquanto irregulariter discussatis; *area* hyalina a medio margine dorsali pinctorum ordine singulari separata.

The genus *Campylosira*, established by GRUNOW in 1882, comprises one recent (*C. cymbelliformis* GRUNOW in VAN HEURCK 1880—5) and two fossil species (*C. japonica* TEMP & BRUN 1889 and *C. Peragalli* HÉRIBAUD, 1902). The new species is distinguished by the outline of its valves, which are broader and have blunter extremities, by the dorsal position of the hyaline area, and by the somewhat decussate puncta. HUSTEDT (1939) has figured a diatom from the North German Coast which resembles that found at Blakeney, except that the valve is longer (20  $\mu$  long and 9  $\mu$  broad) with attenuated apices which are curved ventrally and not straight. He considers it to belong to *C. cymbelliformis* GRUNOW, but it is clear from his figure that it should be combined with the Blakeney *C. alexandrica*.

*C. alexandrica* found especially near mean high water, neap tides, where it is common during spring and early autumn. It is, however, widely distributed on the marsh and should be classed as mesohalobous.

8. *Cymatosira elliptica* SALAH nov. spec. (pl. I, fig. 18—21).

*Valvis* ellipticis, quarum breviores pro portione latiores, aliquando fere circulares, minimae aliquando asymmetricae unum marginem concaviorem quam alii habentes; apicibus plerumque late rotundatis, et in formis asymmetricis apiculatis; valvis brevibus 6—8  $\mu$  longis, latis. 4.5—6  $\mu$ ; superficie valvae punctis rudibus c. 10 in 10  $\mu$  tecta, plerumque in ordinibus longitudinalibus duobus margini parallelis currentibus; *pseudoraphe* ovali vel rotundata; *area centrali* aliquando irregulari.

Although the longer specimens show some resemblance to *C. belgica* GRUNOW, which is 18—30  $\mu$  long and 3.0—4.5  $\mu$  broad (cf GRUNOW in VAN HEURCK 1180—5, PERAGALLO 1897—1908 and HUSTEDT 1937) they are always shorter and broader and with rounded apices; further the puncta are wider apart in *C. elliptica* than in *C. belgica*. In the coarseness of the puncta, this species slightly resembles *C. curvata* CLEVE—EULER (1949, p. 12, fig. 13) which differs in the complete absence of a central area and in the shape of the valves, which are curved like a *Eunotia* or a *Campylosira*.

*C. elliptica* is fairly common in the lower marginal zone of the marsh, particularly in the early spring and late summer. It is also found in rather large numbers in the areas along the creek.

9. *Achnanthes linkei* HUSTEDT. f. *minor* SALAH nov. f. (pl. II, fig. 1)

*Valvis* rhombo-lanceolatis, polis obtusis, 14—20  $\mu$  longis, 6—8  $\mu$  latis; *striis* subtilissimis c. 14—16 in 10  $\mu$ .

This forma differs from the type in its smaller size and finer striae. It is very common on the mud flats, with maximum abundance in early autumn. Position in the halobion system: euhalobous.

10. *Rhoicosphenia stauroneiformis* SALAH nov. spec. (pl. II, fig. 2—3)

*Frustulis* a cinguli latere visis curvis, septis et ligaminibus intercalaribus; *valvis* clavatis dissimilibus, 10—16  $\mu$  longis, 3—4  $\mu$  latis; valva superiore (sine raphe) pseudoraphen angustam, sed aream centralem nullam, habenti; *striis* fere parallelis, 12—14 in 10  $\mu$ ; valva inferiore (raphem habenti) circum axem transversum asymmetrica, leviter in medio constricta, apice superiore obtuso leviterque producta, basi attenuata angusta; *area axiali* distincta; *area centrali* in fascias stauroides dilata margines attingentes; *spatiis* terminalibus latis hyalinis que; *linea mediana* recta, non apices attingente, ad nodulos centrales terminalesque crassiore; *poris centralibus* fere adiacentibus; *striis* validis c. 10 in 10  $\mu$ , fortiter in medio radiatis et in polos in unum vergentibus.

This is distinguished from other species of the genus by its coarser striae and by the shape of the valves, which are slightly constricted with a marked stauroid fascia. It occurs sporadically in the lower marginal zone of the marsh, usually favouring protected situations. Position in the halobion system: euhalobous.

11. *Frustulia directa* SALAH. nov. spec. (pl. II, fig. 4).

*Valvis* angustis, lateribus parallelis, latitudine per longitudinem otam constanti, apicibus rotundatis, 32  $\mu$  longis, 4.5  $\mu$  latis; *linea mediana* costis duabus angustis siliceis latitudinem constantem habentibus saepta; *raphes* ramis rectis; *nodulis terminalibus* parvis; *nodulo centrali* angusto rectangulari; *striis* subtiliter punctatis, centralibus quam aliae prope apices (30 in 10  $\mu$ ) paulo minus crassioribus (28 in 10  $\mu$ ), leviter in medio radiatis et ad apices convergentibus; *striis* longitudinalibus rectis, 30 in 10  $\mu$ .

This differs from other species of the genus by showing no decrease in width of the valves towards the apices. Only a few specimens have been found in gatherings from the lower marginal zone of the marsh.

12. *Frustulia oliveri* SALAH. nov. spec. (pl. I, fig. 22)

*Valvis* lineari-lanceolatis, polis obtusis, in medio saepe inflatione ad margines versus uno in latere facta; longis 28—34  $\mu$ , 6—7  $\mu$  latis; *striis* delicatis, subtilissime punctatis, leviter in medio radiatis, ad apices convergentibus; plerumque 26—8 in 10  $\mu$ , medialibus paulo minus frequentibus, frequentioribus circum polos ad 30 in 10  $\mu$ ; circum centralis noduli marginem in uno valvae latere quam in altero brevioribus, plerumque parallelis vel leviter radiatis; *nodulis terminalibus* paulo distantibus a margine apicali; *nodulo centrali* lato, forma asymmetrica, et in uno valvae latere dilato; *raphe* non recta; *poris centralibus* aliquanto distantibus quorum singuli scissuram transversum in idem valvae latus vergentem habent.

This species resembles *F. hawaiiensis* HUSTEDT (1942b, p. 47, fig. 67) and *F. weinholdi* HUSTEDT (1937—1939, p. 731, fig. 1101) in the presence of transverse slits. The non-rostrate apices and the finer striae distinguish it from the former which has 23 striae in 10  $\mu$ . It differs also from the latter in the size and outline of the valve, in the shape of the central nodule, and especially in the distinctly coarser striae.

It is common in the gatherings from Great Sandy Low, but scarce in other localities, though it becomes exceedingly abundant and dominant in station 8. Position in the halobion system?

The species is named after PROF. F. W. OLIVER.

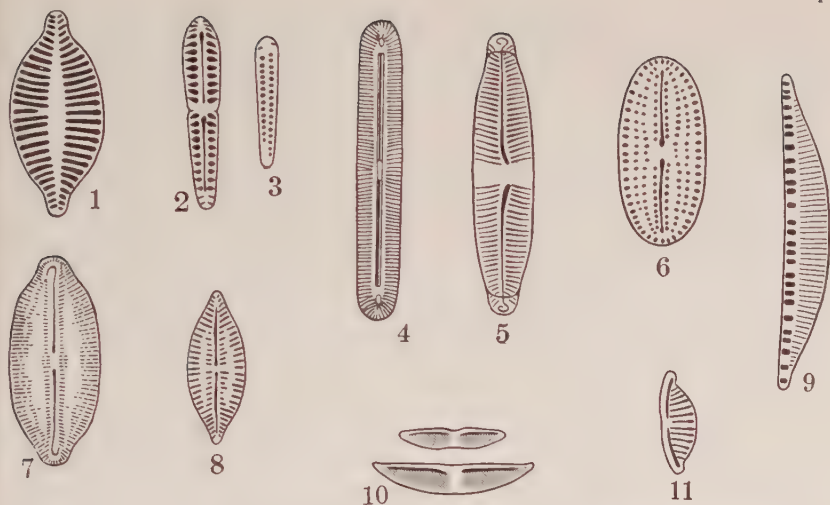
13. *Diploneis pearsalli* SALAH. nov. spec. (pl. I, fig. 23).

*Valvis* latis, lateribus parallelis, apicibus rotundatis, 26—61  $\mu$  longis, 16—19  $\mu$  latis; *nodulis terminalibus* magnis, ab apicibus distantibus; *nodulo centrali* plerumque magno, rectis cornibus; *sulcibus* admodum latis, spatii marginibus suis exterioribus inclusi tertiam quartamve partem includentibus, parallelis, non dilatis adversus nodulum centrale, ordinem ocellorum magnorum habentibus; costis 7—8 in 10  $\mu$ , leviter radiatis, quarum omnes, 3—4 centralibus exceptis, lineam marginalem longitudinalem transversum habent, et cum ordinibus alveolorum distinctorum duplicibus alterant.

This *Diploneis* is distinguished by a marginal longitudinal line, crossing the costae except the 3 or 4 median ones. The latter lack the alternating double rows of alveoli which occur between the others.

*D. pearsalli* is one of the most frequent representatives of the genus at Blakeney Point. Although never recorded from above mean high-water of neap-tides, it becomes an important diatom in station 5. It is found at most times of the year, and being most abundant in early spring. Position in the halobion system: euhalobous.

The species is named after PROF. W. H. PEARSALL F. R. S.



MAP SHOWING THE SITUATION OF STATIONS  
STUDIED IN BLAKENEY POINT; NORFOLK.



14. *Stauroneis flexuosa* SALAH. nov. spec. (pl. II fig. 5).

*Valvis* linearibus, polis leviter rostrato-truncatis, marginibus plerumque parallelis; nonnumquam in medio inflatis, 32—38  $\mu$  longis, 7—8  $\mu$  latis; *striis* 12—14 in 10  $\mu$ , omnino radiatis, nonnumquam curvis, quarum centrales distantiores quam apicales; punctis tectis subtilibus et usque ad apices fere inveniendis; *raphe* leviter flexuosa, ramis in area centrali ad unum valvae latus vergentibus; *area axiali* angusta; *area centrali* transverse dilata in angustum stauron usque ad marginem vergentem ubi paulo latius fit et valvae longitudinis partem sextam vel paulo minus occupat; *lineae medianae* fissurae terminales uncae sunt et eodem spectant; *septis* in troque valvae polo ad interiorem partem usque ad rostrati apicis basim projectis.

The presence of a septum places this species in the subgenus *Pleurostauron*. A similar septum is found in certain Naviculae e.g. *N. ruttneri* HUSTEDT. The new species is nearest in shape to *S. ignorata* HUSTEDT (1939) and *S. minutula* HUSTEDT (1937—1938), but these have much denser striae and a straight raphe. Moreover, it resembles *S. borrichii* var *subcapitata* (BOYE PETERSEN) Lund (1946, p. 64, fig. 3A, B) in the arrangement of the striae, but the latter is distinguished by its peculiar terminal nodules, which are free of markings.

*S. flexuosa* is restricted to station 6, where it is very common. It probably has a preference for the upper and drier parts which are not disturbed by tidal action. Position in the halobion system: oligohalobous.

15. *Navicula rossii* SALAH. nov. spec. (pl. I, fig. 24).

*Valvis* lineari-lanceolatis, ad polos subacutis, plerumque 19—26  $\mu$  longis, raro 14—35  $\mu$ , latitudine fere constanti c. 3  $\mu$ ; *raphe* recta, filo simili, poris centralibus adiacentibus, fissuris terminalibus indistinctis; *area axiali* angustissima; *striis* 26—28 in 10  $\mu$ , in medio parallelis, ad apices leviter convergentibus, ad apicem axialem exstantioribus et crassioribus quam ad valvae marginem; in uno valvae latere interruptis; in altero, stria inveniendi singulari, spatium in utroque latere multo latius habente quam aliae striae; *linea* pura vel languida, depressione in valvae superficie, ut videt, facta, ad ambarum partium iuncturam et per totam valvae longitudinem inveniendi.

This belongs to the *Orthostichae* of CLEVE and seems to be nearest to *N. kryokonites* var *semiperfecta* CLEVE (1883, p. 473, pl. 37, fig. 45) which has a vague unilateral central area. The new species is distinguished by the orientation of the striae on the two sides of the valve. It is one of the most widespread species on the marsh, occurring on a variety of substrata, although usually more conspicuous in the

higher intermediate zone. It tolerates a wide range of habitats between high water of neap and spring tides and is to be classed as mesohalobous and euryhaline.

The species is named after MR. R. ROSS.

16. *Navicula aegyptiaca* SALAH. nov. spec. (pl. II, fig. 17).

*Valvis* ellipticis, polis latis rotundatis, aliquando in medio leviter constrictis, 12—20  $\mu$  longis, 5.5—8  $\mu$  latis; *areis lateralibus* duabus in utroque medianae lineae latere area centrali in unum vergentibus; in medio constrictis, ad polos convergentibus; *striis* c. 14—16 in 10  $\mu$ , radiatis, apicalibus exceptis quae convergunt; duabus lineis longitudinalibus transversis; *punctorum* ordine singulari, ad nodulum centralem interrupto, secundum raphes latera ambo; *raphe* leviter silicea, non apices attingente, poris centralibus aiacentibus.

This resembles *N. auriculata* HUSTEDT (1944, p. 273, fig. 4) and *N. dissipata* HUSTEDT (in A. SCHMIDT, Atl. pl. 403, fig. 7—8), being closer to the former which, according to HUSTEDT, differs from the latter in having narrower valves. Both HUSTEDT's species are distinguished from mine by the single longitudinal line traversing the finer striae and by the fact that the central pores are further apart.

*N. aegyptiaca* is frequent in the lower marginal zone of the marsh, though not sharply limited to this region. It is sometimes found in quantity at varying places along the creek, but mostly from about mean high water level. It appears therefore that it should be classed as mesohalobous.

17. *Navicula samrai* SALAH. nov. spec. (pl. II, fig. 7)

*Valvis* late lanceolatis, polis subrostratis, 22—25  $\mu$  longis, 11—12  $\mu$  latis; *areis lateralibus* magnis, lunatis, ora exteriore indefinita punctisque in lateribus aspersis; *striis* subtiliter punctatis 22—24 in 10  $\mu$ , leviter radiantibus, leniter in polos curvis; *area axiali* angusta, striarum ordine singulari angusto finita non interrupto adversus nodulum centralem, ubi tamen striae breviores sunt quam ad apices; *linea mediana* raphe recta, ad nodulos centrales terminalesque crassiore, fissura terminali aliquantum ab apicibus distante, baculi pastoralis modo flexuosa et versa in contraria valvae latera.

The terminal fissures bend towards opposite sides of the valve at either end. In the shape of the valve and the arrangement of the striae this species resembles *N. concilians* CLEVE (1895, p. 54, pl. 1, fig. 25) from which it is distinguished by its smaller size, its finer striae, and especially the peculiar form of its raphe. Only a few specimens were found. Position in the halobion system: euhalobous.

The species is named after DR. I. SAMRA, Director of the Institute of Hydrobiology, Alexandria.

18. *Navicula taylori* SALAH nov. spec. (pl. I, fig. 25)

Valvis angustis linearibus, in medio leviter convexis, apicibus abtusis rotundatis, 18—28  $\mu$  longis, 3—4  $\mu$  latis; raphe recta, filo simili, poris centralibus adiacentibus; area axiali distincta; area centrali magna, ad partes exteriores latiore; striis c. 12 in 10  $\mu$  punctatis, leviter radiatis; striae tamen quae areae centrali sunt proximae partem brevem habent solam marginemque in altero, valvae latere ambo-busve non attingunt.

This is distinguished from the other species of the section *Lineolatae* CLEVE by the shape of the central area. *N. diserta* HUSTEDT (1939, p. 627, fig. 78—79) possesses similar striae, but differs from *N. taylori* in the smaller central area, and in the less radial striae, the single one opposite the central nodule being shortened and standing further from its neighbours.

*N. taylori* is found at all times of the year in great quantity and may be dominant in the higher intermediate regions of the marsh (Stations 4, 2, 1). Though not infrequent, it is scarce in the other zones of the marsh. It should therefore probably be classed as meso-halobous (perhaps euryhaline).

This species is named after DR. G. TAYLOR.

19. *Navicula margino-ornata* SALAH. nov. spec. (pl. I, fig. 26).

Valvis brevibus, ellipticis ovalibus, apicibus rotundatis, 10—14  $\mu$  longis; 6—8  $\mu$  latis; striis brevibus marginalibus, in media valva spatium lanceolatum latum hyalinum linquentibus, 18—20 in 10  $\mu$ , non visibiliter punctatis; raphe in costa silicea valida, ab apicibus ad mediam valvam angusta, ad nodulum centralem subito angustissima; partibus dimidiis aliquantum arcuatis; poris centralibus adiacentibus.

*N. margino-ornata* resembles *N. obsidialis* HUSTEDT (1942a, p. 68, fig. 1—3) in form and size, as well as in the distribution of the striae, but differs markedly in the siliceous thickening of the raphe and the non-punctate striae.

This uncommon diatom was met only on a few occasions near mean high water of neap-tides, and very rarely in the areas along the creek.

20. *Navicula finmarchica* CLEVE et GRUNOW, var. *acuta* SALAH nov. var. (Pl. II, fig. 8).

Valvis brevibus, late lanceolatis, apicibus acutis, 14—16  $\mu$  longis, 6—8  $\mu$  latis; nodulo centrali transverse in stauron brevem dilato; striis levibus, 16—18 in 10  $\mu$ , omnino radiatis, area transversa angusta lateralim arcuata.

This differs from the type in its shape, size and finer striae.

(*N. finmarchica* is 30—42  $\mu$  long and 11—13  $\mu$  broad, and has 12—

14 striae in  $10\ \mu$  cf. *Stauroneis finmarchica* CLEVE & GRUNOW 1880, p. 47, pl. 3, fig. 63; and *Navicula finmarchica* (CLEVE & GRUNOW) CLEVE, 1895, p. 28).

*N. finmarchica* is very common on the Arctic coasts of Europe; its only other record is that of HUSTEDT (1939) from the North German Coast. The variety is fairly common in the lower marginal zone of the marsh, where it shows a maximum abundance in early autumn.

21. *Amphora sabyii* SALAH. nov. spec. (pl. II, fig. 10).

Frustulis ellipticis, leviter in medio constrictis, polis truncatis; valvis angustis c.  $2-3\ \mu$  latis polis acutis,  $6-15\ \mu$  longis; media parte constricta; raphe recta, crassitudine constanti, margini ventrali adiacente; nodulis centralibus latis, transversae ad stauron latum dilatis; striis, ut videt, transversis delicatis in valvae latere dorsuali (centralibus exceptis).

Its extremely hyaline structure renders this species quite distinct from the others belonging to the subgenus *Oxyamphora* CLEVE. It is nearest to *A. levissima* var. *perminuta* (GRUNOW) CLEVE (1895, p. 13; cf. Peragallo, 1897—1908, pl. 49, fig. 10), from which it is distinguished by the delicate scarcely visible striae, the wider stauros, and the shorter valves which are constricted in the middle with acute apices.

*A. sabyii* is one of the commonest diatoms at Blakeney Point. It has been found in different places, but mostly from near mean high tide mark. The wide range of level and the region of greatest abundance show that it is mesohalobous and euryhaline.

The species is named after DR. M. K. EL-SABY, the former Director of The Marine Hydrobiological Station at Alexandria.

22. *Amphora ramsbottomi* SALAH. nov. spec. (pl. I, fig. 27).

Frustulis elliptico-lanceolatis, polis truncatis; zona divisionibus multis indistinctis longitudinalibus; valvis semi-lanceolatis, gradatim a medio ad polos versus angustos acutos fastigantibus; marginibus dorsalibus arcuatis, ventralibus rectis,  $16-20\ \mu$  longis,  $3-4\ \mu$  latis; raphe recta margini ventrali proxima; area axiali indistincta; nodulis terminalibus puris; striis in latere dorsuali c. 14 in  $10\ \mu$ , non punctatis, paulo in medio distantioribus, omnino fere parallelis; latere ventrali angustissima, marginalem punctorum ordinem singularem habenti.

The shape of the velle slightly resembles that of *A. acutiuscula* KÜTZ. (cf. CLEVE 1895 p. 121), which is larger ( $35-70\ \mu$  L) and has more densely arranged striae ( $18-20$  in  $10\ \mu$ ). In the arrangement and density of striation, *A. ramsbottomi* approaches *A. strigosa* HUSTEDT



(1949, p. 44, fig. 30) which has valves of similar size and outline, but it is distinguished by its curved raphe, as well as by the broad axial area on the dorsal side of the valve.

This diatom is rather uncommon; few specimens have been obtained from the lower marginal zone and occasionally along the creek between tide marks. The species is named after DR. J. RAMSBOTTOM.

23. *Amphora extensa* SALAH. nov. spec. (pl. I, fig. 28).

Frustulis angustis rectangularibus, leviter ad polos rostratos contractis, 53—80  $\mu$  longis; zona simplici sine divisionibus; valvis angustis 4—5  $\mu$  latis, marginibus dorsalibus levissimo arcuatis, ventralibus rectis, polis productis; area axiali angustissima; raphe filo simili, lateri ventrali proxima, polis exstantioribus leviterque in latius dorsuale arcuatis; nodulo centrali elongato; striis non punctatis; in latere dorsuali c. 14 in 10  $\mu$ , parallelis omnibus nisi quod ad apices convergunt; earum quae nodulum centralem finiunt una pluresve breviores quam aliae; ventralibus ex ordine punctorum singulari factis ad valvae marginem (extra centralis noduli aream) dispositorum, plerumque quam dorsuales frequentioribus.

This *Amphora* is characterised by its elongate slender outline. In girdle view, the frustule resembles that of *A. arcta* A. SCHMIDT (Atlas pl. 26, fig. 63), but differs in size and the coarse striation (frustule hyaline in *A. arcta*.)

*A. extensa* is common throughout the year in the lower marginal zone, where it shows a maximum abundance in early spring. It has not been found higher than the neap-tide zone and is to be classed as euhalobous.

24. *Amphora tropidoneioides* SALAH. nov. spec. (pl. I, fig. 29).

Valvis semi-lanceolatis, hyalinis, apicibus obtusis 16—20  $\mu$  longis (raro ad 24  $\mu$ ) 3—3.5  $\mu$  latis; area axiali angusta; raphe leviter excentrica, margini ventrali proxima; striis subtilissimis, non resolutis.

This *Amphora* which is characterised by the membranous structure of the valves is nearest to *A. sabyii* SALAH, but it is distinguished by the longer valves, which are not constricted in the middle, and by the absence of a stauros. It is frequent in the lower marginal zone of the marsh, to which it is confined. Position in the halobion system: euhalobous.

25. *Amphora cingulata* Cl. var. *hyalina* SALAH nov. var. (pl. I, fig. 30).

Valvis rectangularibus, polis rotundatis, 34—40  $\mu$  longis, 6—7.5  $\mu$  latis; raphe curva, in media valva vergenti ad ventralem marginem, ubi stauros est angustus; striis subtilissimis, non resolutis, paene invisibilibus.

This differs in not only reaching the minimum size of the type (65  $\mu$  cf. Peragallo) but also in the nearly invisible striation. (CLEVE 1878 and DE-TONI 1891—4 give for the type 15 striae in 10  $\mu$ , while PERAGALLO 1897—1908 gives 17—21 in 10  $\mu$ .) Position in the halobion system: euhalobous.

26. *Amphora turgida* GREGORY. var. *wisei* SALAH. nov. var. (pl. II fig. 11)

Frustulis orbicularibus, parvis; valvis 8—13  $\mu$  longis, 2.5—3.5  $\mu$  latis; striis c. 16—18 in 10  $\mu$ , leviter in medio, fortiter ad valvae polos radiatis frequentioribusque.

This variety differs from the type, by its smaller, denser striae and the slightly capitate ends. (GREGORY 1857 gives 9, PERAGALLO 1897—1908 7 while CLEVE 1895 13 striae in 10  $\mu$  for the type.) Fairly common in the lower marginal zone of the marsh, although sometimes recorded from localities along the creek. It is named after MR. F. C. WISE, F.R.M.S.

27. *Cymbellonitzschia hossamedinii* SALAH. nov. spec. (pl. II, fig. 9).

Valvis cym bellae formam habentibus, 20—25  $\mu$  longis, 4—5  $\mu$  latis; margine ventrali leviter curvo, dorsuali arcuato et ad apices acutos versus attenuato; carina superimposita, lata, punctis carinalibus 11—12 in 10  $\mu$ , striis 18—20 in 10  $\mu$ , non punctatis.

The genus *Cymbellonitzschia*, established by HUSTED in 1924, comprises two freshwater species, one recent (*C. deluviana* HUSTEDT 1950) and the other fossil (*C. minima* HUSTEDT 1924 in A. SCHMIDT Atlas). *C. hossamedinii* is distinguished from them by having longer valves with acute extremities, by the coarser striae and the finer carinal canaliculi; together with the difference in habitat.

Only a few specimens were found at station 5. Position in the halobion system: euhalobous. This species is named after Dr. A. HOSSAM EL-DIN, FORMER Director of The Egyptian Education Bureau, London.

28. *Nitzschia janei* SALAH. nov. spec. (pl. I, fig. 31).

Frustulis linearibus, in medio constrictis, polis rotundatis; valvis linearibus leviter in medio constrictis, ad apices acutos versus attenuatis, 57—72  $\mu$  longis, 6—6.5  $\mu$  latis; carina excentrica, lata; punctis carinalibus 5—7 in 10  $\mu$  leviter trans valvam intervallis inaequalibus prolongatis, duobus medianis distantioribus; striis 14 in 10  $\mu$ , punctis rudibus c. 14—16 in 10  $\mu$ .

This *Nitzschia* is distinguished from the other species of the section *Bilobatae* GRUNOW by the arrangement of the puncta in more or less irregular longitudinal rows, as well as by the coarser striae and the

acute apices of the valves. *Nitzschia fagedi* MOLLER (1950, p. 212, fig. 14) has a similar keel and the same number of carinal canaliculi, but it has 29 striae in  $10\ \mu$  and its apices are capitate. In the coarseness and arrangement of the puncta *N. janei* is near to certain forms of *Hantzschia* e.g. *H. distincte-punctata* HUSTEDT (in A. Schmidt Atlas, pl. 329), but it has not the asymmetry of that genus.

*N. janei* is one of the most frequent and widespread species of *Nitzschia* at Blakeney. In general it is exceedingly abundant in the higher regions (Station 4, 2, 1) and less so in the lower marginal zone (Station 5). It is therefore to be classed as mesohalobous. The species is named after PROF. F. W. JANE.

I take much pleasure in expressing my grateful thanks to DR. G. TAYLOR, DR. J. RAMSBOTTOM and MR. R. ROSS of the British Museum (Natural History), London, where this work was carried out. My thanks are also due to Profs. W. H. PEARSALL F.R.S. and F. W. JANE.

# The attached algal flora of slow sand filter beds of waterworks<sup>1)</sup>

by ALAN J. BROOK,

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## 1. INTRODUCTION.

The algae living on the bottom of the slow sand filters of the Newcastle and Gateshead Water Company at Whittle Dene, Northumberland were described in an earlier paper (BROOK 1954). A further study was made of those attached to the stonework of the beds in order to compare the composition of this community with that present on the relatively unstable, sandy bottom. Since the environmental conditions of a filter are in many respects like those of a river, it is of interest to compare the data with those obtained by BUTCHER (1932b, 1940, 1946) in studies of the attached communities of rivers.

## 2. METHODS

Glass microscope slides, fitted into specially constructed, weighted, wooden frames (BUTCHER 1932a) were placed on the stone steps of the filters, being submerged at approximately 18 inches below the surface of the water; the depth varied slightly with the level of the water. At the beginning of each month a frame with four slides was placed in each of the four most recently cleaned beds, one slide being removed from each frame after one, two, and four weeks respectively, while the fourth was usually left for a further two or more weeks in order to obtain older growths of certain Chaetophoraceae for easier identification.

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<sup>1)</sup> This paper forms part of a thesis accepted for the Degree of Doctor of Philosophy by the University of Durham. Complete tables relating to the subject-matter of this paper are given in the thesis, which can be consulted in the library of King's College (Univ. of Durham) Newcastle on Tyne.



The principal types of algae found on the slides were:

- I. Filamentous Chlorophyceae and Diatoms.
- II. Stalked Diatoms (*Cymbella*, *Gomphonema* and *Synedra*) which are loosely attached by a mucilaginous pedicel.
- III. a) Diatoms attached by the whole of one surface, e.g. *Cocconeis*, *Achnanthes*, *Amphora*, etc.  
b) Thalloid Algae (mainly Chlorophyceae), firmly attached by mucilage or other means, the commonest representatives being Chaetophorales with well-developed prostrate systems, such as *Stigeoclonium* spp., *Coleochaete* spp., and *Protoderma* spp.

The distribution of filamentous and stalked diatoms was frequently irregular. For example, stalked diatoms were at times common on the frames, but only present in small amounts on the slides. On other occasions filamentous diatoms produced a felt, almost an inch deep over slides and frames, so that numerical estimation was impossible. The amount of the growths included under I and II above has therefore merely been expressed by symbols (abundant, common, frequent, etc.), a method which is by no means completely satisfactory, since ecologists in other fields (HOPE-SIMPSON 1940, SMITH 1944) have shown that different observers vary widely in their concepts of say, "common" as distinct from "abundant", and that a given observer's estimates vary from day to day. In order to minimise the error as far as possible, the following scale of values has been used in estimating degrees of abundance of a species:

Abundant (A), when a distinct felt was present.

Common (C), when patches occurred in every one of 20 low power fields under the microscope.

Frequent (F), when the species was seen in 10 of 20 low power fields.

Occasional (O), when seen in more than two, but less than 10 of 20 fields.

Rare (R), when seen in 2 or fewer of 20 fields.

The remaining growths (category III) were mostly analysed by counting the number of cells of the different species present in 10 to 200 fields, selected at random on each slide, under a 1/6 in. objective; the number of fields examined depended on the abundance and homogeneity of the material (GODWARD 1937). When the growths were so considerable that direct counts were impossible, the filamentous and stalked diatoms, after estimation, were carefully removed with a fine camel-hair brush, leaving the attached algae below essentially undisturbed. The most abundant of these was *Achnanthes*, which at times attained a density of several thousands per sq. mm, so that

direct counts were again impossible. Estimates were then made by comparing the density of the growth with a series of photomicrographs of a carefully counted range of densities.

On occasions when *Achnanthes* completely covered some of the Chaetophoraceous prostrate systems, as well as diatoms like *Cocconeis placentula*, its growths were also removed with the brush after their density had been determined. Though this treatment also removes diatoms like *Cymbella ventricosa*, *Nitzschia acicularis* and *N. palea*, whose abundance can therefore then not be estimated, the firmly attached forms remain undisturbed.

The estimation of numbers of cells in the, often large, prostrate systems of Chaetophoraceae was facilitated by determining for each of the principal species, the average number of cells in one quarter of the high power field of the microscope. For example, previous counting having shown that 480 cells of the prostrate system of *Chaetopeltis orbicularis* on an average occupy  $\frac{1}{4}$  of this field, an individual taking up approximately  $\frac{1}{8}$ th of the field was recorded as containing 240 cells. In small individuals the number of cells was counted directly.

### 3. THE COMPOSITION AND PERIODICITY OF THE ATTACHED FLORA

#### a) Monthly variations in the total amount of algae present



Fig. I.

Total abundance of all filamentous Algae and stalked Diatoms.

Fig. 1 shows the monthly variations in abundance of filamentous algae and stalked diatoms (cf. table 1). Values, from 1 for 'rare' to 5 for 'abundant', have been allotted to the different symbols indi-

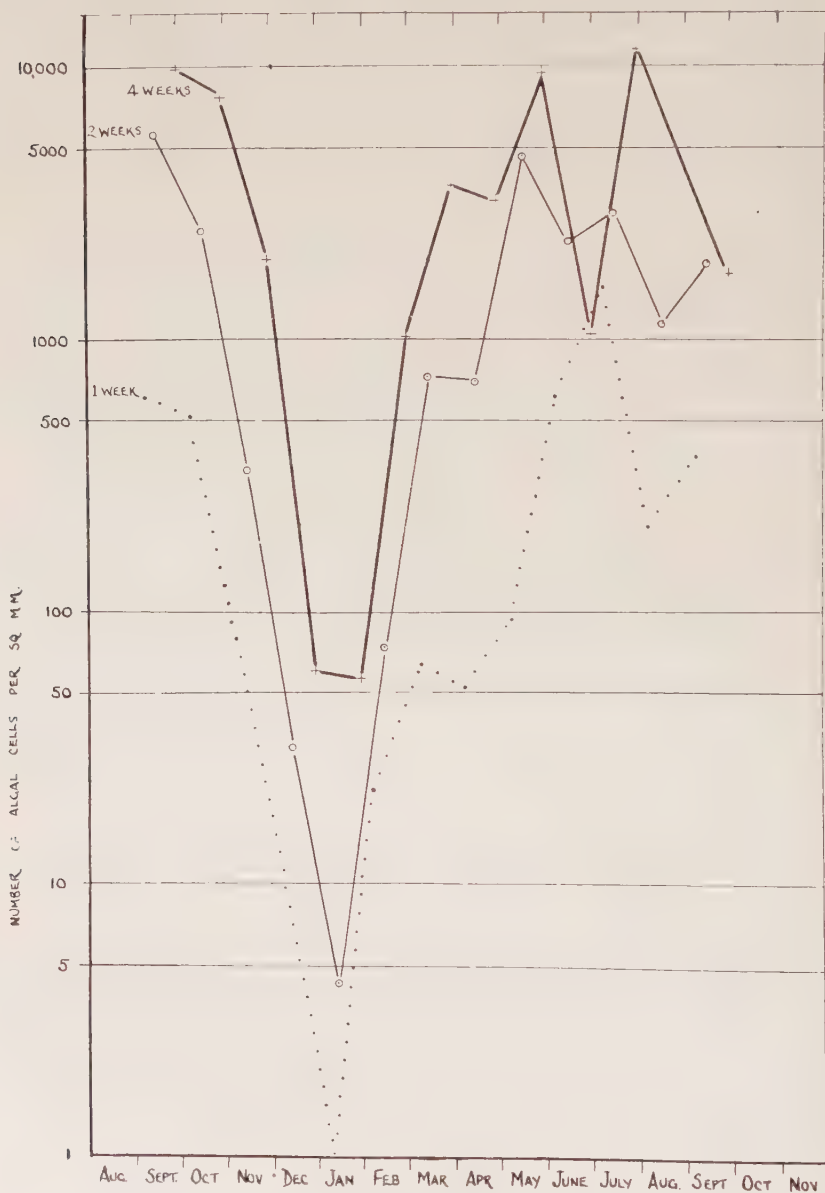


Fig. 2.

Total amount of epiphytic Diatoms and Thalloid Algae on slides.

cating abundance (p. 2), and the total for each month has been calculated as the sum of the separate values for each species, using the maximum abundance recorded. This was not necessarily encountered on slides from beds which had been in operation for the longest time (cf. pp. 10—11).

Fig. 2 represents the total maximum monthly amounts of algae in category III (p. 2) expressed as the number of cells per sq. mm. Since the annual variation is very great, this is plotted on a logarithmic scale. The three graphs show the numbers of algae on slides submerged for one, two and four weeks respectively.

The two figures suggest an annual growth cycle, with a minimum in winter, and maxima for filamentous and stalked algae in spring, and one for the remaining algae in summer. Between November and March the form of the graphs is fairly smooth, but from March onwards there are irregular fluctuations. The graphs (BUTCHER, 1946) of the total growth of algae in the River Itchen, and in a pond at the Arlesford Station, exhibit similar irregular fluctuations which are attributed to (1) quickly changing external factors, (2) the browsing of animals, (3) the detachment of algal films through the formation of gas bubbles, and (4) the erosive effect of foreign bodies carried by the current. Of these only the second and third need be considered in relation to the filter-bed flora.

Detachment of filamentous species has been occasionally observed, but these grow above those more firmly attached, which, except for occasional *Achnanthes*, have never been found among the former. Detachment can therefore be responsible only for very minor fluctuations in the numbers of the algae. The feeding of aquatic animals on the latter may throw light on many so far unsolved questions relating to algal periodicity (cf. BROOK 1954). The fluctuations in the attached population between March and October were indeed in the main caused by the depredations of the larvae of aquatic insects (see p. 12).

#### b). *Seasonal variation in the composition of the Flora*

Table 1 sets out the average numbers of cells of the principal species on slides exposed for one, two and four weeks. It indicates a definite periodicity, with four fairly distinct phases, each phase lasting for approximately three months. Although some of the common species persist, the dominant ones tend to differ from phase to phase. The principal species present during these four periods were as follows:



*Spring phase* (February to April). *Fragilaria capucina* Desm., *Diatoma elongatum* Ag., *Gomphonema olivaceum* (Lyngb.) Kütz., with *Sphaerobotrys fluviatilis* Butcher, *Protoderma* sp., and *Achnanthes minutissima* Kütz. *Cymbella cistula* (Hemp.) Grun., *Chlorosphaera Klebsii* Vischer. *Chrysochaete britannica* (Godw.) Rosenberg and *Protoderma viride* Kütz. were common at times.

*Summer phase* (May to July). *Fragilaria capucina*, *Diatoma elongatum* and *Achnanthes minutissima*. In the latter part, several thalloid forms and *Microcystis parasitica* were common, while the palmelloid stage of a *Chlamydomonas* (?) became abundant in July.

*Autumn phase* (August to October). *Melosira varians* C. A. Ag., *Fragilaria capucina*, *Achnanthes minutissima*, with the palmelloid stage of the same *Chlamydomonas* (?). *Coleochaete irregularis* Pringsh., *Sigeoclonium farctum* Berth., and *Chaetopeltis orbicularis* Berth. were very common throughout, while *Microcystis parasitica* and *Cocconeis placentula* Ehr. were common in October.

*Winter phase* (November to January). *Melosira varians*, *Fragilaria capucina*, *Cocconeis placentula*, *Ulvella frequens* Butcher, and *Achnanthes minutissima* were dominant until December. In January the number of algae present was very small, though *Sphaerobotrys*, *Chlorosphaera* and *Protoderma* sp. began to appear on the slides.

Periodic chemical analyses of the water flowing through the filters during the present investigations showed the usual marked depletion of dissolved salts and organic matter in spring. The concentrations remained low throughout the summer and early autumn, when replenishment took place, so that during winter and early spring the quantities of dissolved substances were again high. In late spring, summer and early autumn the condition may be regarded as oligotrophic, while during the remainder of the year it approaches a eutrophic state. Although the communities, — *Achnanthes* — *Chaetopeltis* and *Cocconeis* — *Ulvella* — related by BUTCHER (1946) to oligotrophic and eutrophic conditions respectively in rivers, were not found at Whittle Dene, *Achnanthes* and *Chaetopeltis* were abundant during the oligotrophic period, while *Cocconeis* and *Ulvella* were most abundant during the winter months, when the water in the filters was richest in nutrients.

A list of the species found, apart from those mentioned above, will be found at the end of this paper.

#### 4. ALGAL SUCCESSION

The data in Table 1 show that, in general, the order of frequency and the relative quantities in which the principal species occur is much the same on the three slides removed each month. There are however, considerable differences in both respects in different months. Although certain species (e.g. *Chaetopeltis* and *Microcystis* in September) become dominant on the 4 weeks' slides, they are clearly additional and do not replace others. Similarly, the *Achnanthes* and *Chrysochaete* developing late in March and April do not replace the *Sphaerobotrys* and *Stigeoclonium* which colonised the slides rapidly during the first week or so. In neither instance is there any succession.

During May, June and July, when conditions seemed most favourable for the growth of *Achnanthes*, there were indications that it might eventually replace some of the green algae (mainly Chaetophorales). In May the latter constituted more than 50% of the total flora at the end of the first week, but by the second week they had become densely overgrown by *Achnanthes* which then formed 99% of the total population. Not only was all available space occupied, but many of the green growths were completely covered by the diatom, so that their further development must have been greatly restricted. Although there was competition for space, there was no actual replacement since the green forms persisted beneath the *Achnanthes*. Had the slides been left longer, a succession might have occurred owing to death of the smothered algae.

The various species are, however, not all affected by *Achnanthes* to the same degree. Those whose cells are embedded in a well-defined mucilage sheath (*Apiocystis*, etc.) never bore *Achnanthes* as an epiphyte. The latter was never found on the older stages of *Stigeoclonium* spp. with well-developed systems of erect hairs or branches, nor on *Chrysochaete britannica*, though the prostrate systems were sometimes overgrown before the erect system developed. Chaetophorales, like *Protoderma*, *Ulvella*, *Coleochaete* and *Chaetopeltis*, with a feebly developed or absent erect system were most frequently covered by *Achnanthes* and probably suffer most in competition for space.

#### 5. COLONISATION

In Fig. 3 the total growth on the slides is plotted for each month on a logarithmic scale, the three points for the first, second and fourth weeks of submergence being joined to give graphs showing the progress of colonisation. Their slope, which is directly related to the

Table 1

## OCCURRENCE OF PRINCIPAL ATTACHED ALGAE

(1, 2, 4, number of weeks of submergence of slides; *a*, numbers of cells per sq. mm.  $\pm 10^{-1}$ ; *b*, percentage occurrence of species. *R* = rare; *O* = occasional; *F* = frequent; *C* = common; *A* = abundant).

<i>Autumn Phase</i>	AUGUST				SEPTEMBER				OCTOBER			
	1		2		4		I		2		4	
	<i>a</i>	<i>b</i>	<i>a</i>	<i>b</i>	<i>a</i>	<i>b</i>	<i>a</i>	<i>b</i>	<i>a</i>	<i>b</i>	<i>a</i>	<i>b</i>
<i>Fragilaria capucina</i>	R	—	R	—	—	—	C	—	—	—	—	—
<i>Melosira</i> varians	R	—	O	—	R	—	C	—	—	—	R	—
<i>Achnanthes minutissima</i>	12	56	49	44	167	41	19	31	171	30	396	40
<i>Coleochaete irregularis</i>	4	18	35	31	158	26	4	6	44	8	132	8
<i>Chlamydomonas</i> sp.	5	24	10	9	43	10	9	15	72	13	99	6
<i>Stigeoclonium farctum</i>	—	—	3	3	31	8	22	35	183	32	292	18
<i>Chaetopeltis orbicularis</i>	—	—	—	—	3	—	—	—	81	14	390	25
<i>Microcystis parasitica</i>	—	—	2	1	5	—	2	3	29	5	97	6
<i>Cocconeis placentula</i>	+	—	+	—	3	—	1	2	8	—	10	—

<i>Winter Phase</i>	NOVEMBER				DECEMBER				JANUARY			
	1		2		4		I		2		4	
	<i>a</i>	<i>b</i>	<i>a</i>	<i>b</i>	<i>a</i>	<i>b</i>	<i>a</i>	<i>b</i>	<i>a</i>	<i>b</i>	<i>a</i>	<i>b</i>
<i>Fragilaria capucina</i>	R	—	R	—	F	—	R	—	—	—	—	—
<i>Melosira</i> varians	R	—	R	—	C	—	R	—	—	—	—	—
<i>Achnanthes minutissima</i>	2	34	14	42	108	55	+	30	+	28	1	23
<i>Cocconeis placentula</i>	2	34	1	3	14	7	+	30	+	22	2	30
<i>Ulvella frequens</i>	1	30	7	20	25	13	+	40	1	44	2	35
<i>Microcystis parasitica</i>	+	2	4	13	38	19	—	—	—	—	—	—
<i>Stigeoclonium farctum</i>	+	—	5	15	10	5	+	—	—	—	—	—





rate of colonisation, becomes increasingly steep throughout spring and nearly approaches the vertical in summer. Later, it again becomes less steep, being flattest in December and January.

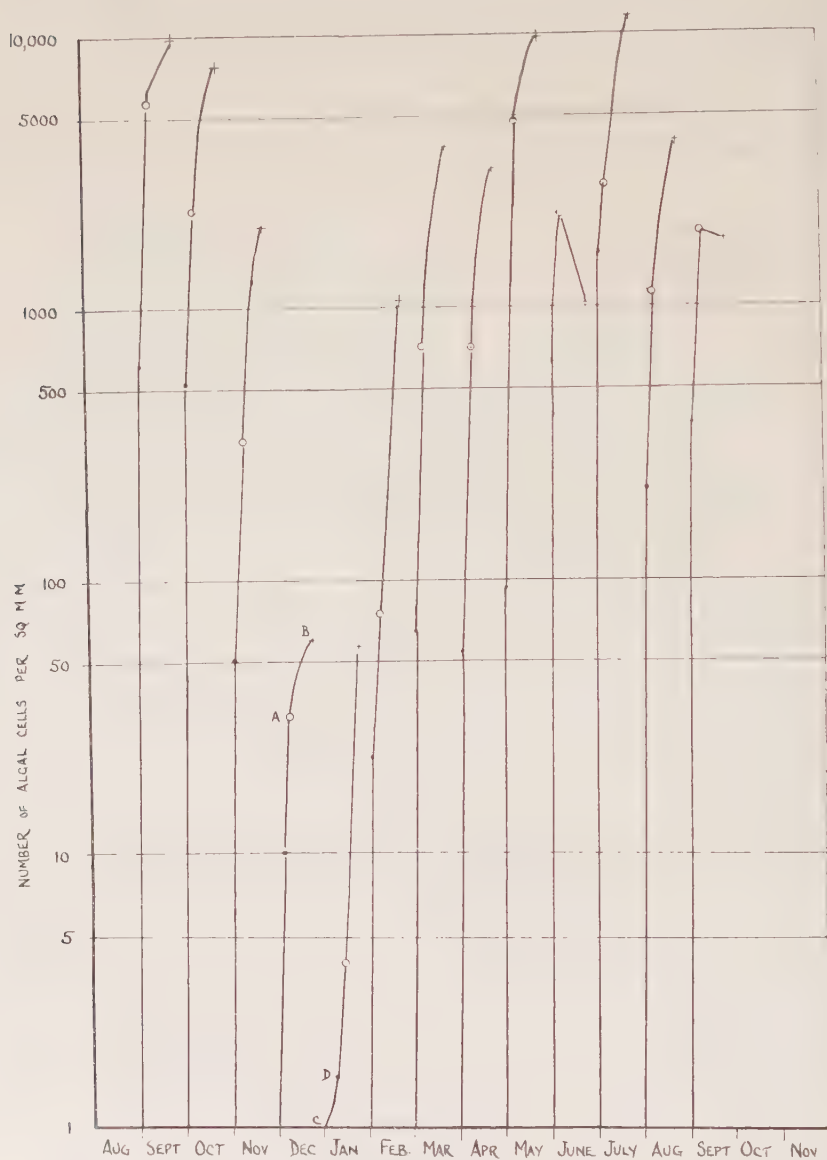


Fig. 3.

Rate of Colonisation of Slides by Epiphytic Diatoms and Thalloid Algae.

Throughout most of the year the graphs for the first two weeks are almost straight lines. Since they are plotted on a logarithmic scale, it may be concluded that the rate of colonisation during the first fortnight usually followed a compound interest law.

Exceptions are seen in December and January. In December the slight decrease after the first and the marked decrease after the second week (A and B in fig. 3) can be related to low temperature and low light intensity, the effects of which are apparent from October onwards. The rate of colonisation in January is considerably less during the first two than during the last two weeks, and the slope of the graph for the first week (between C and D) resembles that for the latter part of December (A and B). Further, the slope for the last two weeks of January is approximately the same as that for the first two weeks in December, so that the whole graph for January is more or less of an inversion of the December one. A complete graph from the beginning of December to the end of January would therefore be a sigmoid one, with its point of inflection in the last week of December. This suggests that, at this time of the year, the rate of colonisation is related to light intensity rather than to temperature, which did not reach a minimum until January.

From May to September the graphs for the last two weeks are less steep than those for the first two, that is there is a slowing down in the rate of colonisation. In June and September there was actually a decrease in numbers of algae, which can be attributed to the feeding of aquatic animals. Although this may have occurred also during the first two weeks, its effects will be increasingly marked as the number of animals increase, until the rate of feeding exceeds the rate of algal reproduction.

As the amount of free space on a slide diminishes, it becomes increasingly difficult for further algae to gain a foothold, although those already present may spread at a steady rate. The difficulty of colonisation by new individuals will continually increase particularly in the case of the thalloid forms (IIIb, on p. 2) which require a smooth surface and seem unable to establish themselves on an area largely occupied by other algae.

## 6. DIFFERENCES IN THE ATTACHED FLORA IN FILTER BEDS OF DIFFERENT AGES.

Marked differences in composition and amount of algal growth were found on slides in filter beds which had been in operation for different lengths of time (see Table 1). The contrast was particularly apparent in June with respect to filamentous and stalked diatoms, several of which were 'occasional' or even 'frequent' in the newer beds, but

'rare' or absent in the less recently cleaned ones. Disappearance was always associated with an abundance of insect larvae (Ephemeroptera, Trichoptera, many Chironomids), and dissection showed that they were largely responsible for the removal of the diatoms (cf. also BROOK 1954). The tube — like shelters of the Chironomid larvae, always abundant on the slides in the oldest beds, were composed almost entirely of diatoms, bound together by delicate threads. Decrease in numbers of diatoms may therefore not only be due to feeding, but also to the tube — building activities of the larvae.

The differences in amounts of other algae (*Achnanthes*, *Cocconeis*, *Ulvella*, *Chaetopeltis*, *Protoderma*, etc.), in beds of different ages, were not so marked, although there were generally more of them on slides from 'old' than from 'new' beds. In June and September, however, *Achnanthes* at times disappeared, and examination of the guts of the larvae present indicated that they were feeding almost exclusively on this diatom. The removal of *Achnanthes* at other times might possibly have been much greater had it not been covered by considerable growths of filamentous and stalked diatoms. ALLEE (1945) has suggested that there is automatic biological co-operation, as well as competition, between animals. In relation to the algae here discussed, apart from competition for space, there may also be such automatic co-operation. When an alga reaches water, in which the physical and chemical factors are suitable for its growth, it may fail to establish itself because it is devoured by a member of the fauna. The greater the quantity of other algae present, however, the greater may be its chances of survival. *Achnanthes* may therefore have thrived in the filters at the expense of the filamentous and stalked diatoms.

The latter as well as the rather loosely attached *Achnanthes*, appear to be easily removed by browsing animals. Chaetophoraceae with well-developed erect systems appear to suffer most, while *Chaetopeltis orbicularis*, which is difficult to detach from the slides, even with a scalpel, is never taken. *Cocconeis* and *Amphora* have likewise never been found in the guts of insect larvae, or in the bodies of diatom-eating protozoa (BROOK 1952).

As with the plankton (FRITSCH 1931) and the unattached, bottom-living flora (BROOK 1954), the successful establishment and ultimate composition of the attached flora will at certain times of the year be largely dependant on the magnitude of the alga-eating fauna.

## SUMMARY.

1. The paper presents the results of an investigation of the attached algal flora, as estimated by the growths on slides, of the slow sand filter-beds of the Whittle Dene Waterworks, Northumberland.

2. The flora consists largely of filamentous and attached diatoms and Chaetophoraceae and shows marked seasonal differences in composition and abundance. Then community is compared with that of rivers.

3. The factors influencing seasonal differences, colonisation, and succession are examined.

4. Differences in the attached flora of beds which have been in operation for different lengths of time are considered in relation to the aquatic fauna.

The author expresses his thanks to Mr. S. G. Barrett, Chief Engineer, to Dr. A. T. Palin, Waterworks Chemist of the Newcastle and Gateshead Water Company, and to Mr. A. Lishman, Foreman at the Whittle Dene Waterworks, for their generous cooperation during these investigations and to the late Prof. F. E. Fritsch F.R.S. for kindly revising the manuscript of this paper.

*Algae* (other than those listed on p. 6) *found on Slides in the Filter Beds*

## I. CHLOROPHYCEAE

*Palmodictyon varium* (Naeg.) Lemm.

*Apiocystis Brauniana* Naeg.

*Characium Sieboldii* A. Br.

*C. Pringsheimii* A. Br.

*Ulothrix moniliformis* sec. Borge. ?? (cf. PASCHER, Süßw. Fl. 6, p. 49, fig. 63).

*U. zonata* (Web. & Mohr.) Kütz.

*Hormidium flaccidum* A. Br.

*Stigeoclonium amoenum* Kütz.

*S. falklandicum* var. *anglicum* Butcher.

*Aphanochaete repens* A. Br.

*Gongrosira viridis* Kütz.

*Coleochaete soluta* Pringsh.

*C. scutata* Bréb.

*Chaetosphaeridium globosum* (Nordst.) Kleb.

*Pleurococcus* sp.

*Oedogonium* spp.

*Bulbochaete* spp.

## II. XANTHOPHYCEAE

*Chlorobotrys regularis* (West) Bohlin.



### III. BACILLARIALES

- Tabellaria fenestrata (Lyngb.) Kütz.  
Diatoma vulgare Bory var. capitulata Grun.  
D. vulgare Bory var. brevis Grun.  
Ceratoneis arcus (Ehr.) Kütz.  
Fragilaria capucina Desm. var. mesolepta (Rabh.) Grun.  
Synedra ulna (Nitzsch.) Ehr.  
S. ulna (Nitzsch.) Ehr. var. biceps (Kütz.) Grun.  
S. acus Kütz.  
S. rumpens Kütz.  
S. pulchella Kütz.  
Cocconeis pediculus Ehr.  
Achnanthes minutissima Kütz. var. cryptocephala Grun.  
A. exilis Kütz.  
A. affinis Grun.  
Pinnularia Debesii Hust.  
Amphora ovalis Kütz.  
A. ovalis Kütz. var. libyca (Ehr.) Cl.  
Cymbella naviculaeformis Auersw.  
C. prostrata (Berkely) Cl.  
C. cistula (Hemp.) Grun. var. maculata (Kütz.) Van Heurck.  
C. cistula (Hemp.) Grun., var. incistula May.  
Cymbella helvetica Kütz.  
Gomphonema acuminatum Ehr.  
G. parvulum (Kütz.) Grun.  
G. sphaerophorum Ehr.  
G. constrictum Ehr.  
Denticula tenuis Kütz. var. crassula (Naeg.) Hust.  
Epithemia turgida (Ehr.) Kütz.  
Nitzschia palea (Kütz.) W. Sm.  
N. acicularis W. Sm.

### IV. MYXOPHYCEAE

- Oncobyrsa rivularis Kütz., emend. Geitl.  
Chamaesiphon regularis (Fritsch) Geitl.  
Phormidium tenue (Menegh.) Gom.  
P. molle (Kütz.) Gom.

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# Riesenwuchs auf verrotteten Halmen von *Scirpus lacustris* L.

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Während die abgestorbenen Halme von *Phragmites communis* über Winter, oft sogar bis in den Frühsommer, an der Pflanze verbleiben und nach der Loslösung vom Rhizom sehr schwer verrotten, verhält sich *Scirpus lacustris* L. darin gänzlich anders: Die abgestorbenen Halme oder auch nur die abgestorbenen Halmteile werden über Winter von der Pflanze durch Sturm oder Eisbildung getrennt. Da sie ein sehr geringes spezifisches Gewicht haben, setzt sie der Wellenschlag als „Treibsel“ am Ufer ab und dort zerfallen sie in wenigen Monaten. Sie werden dann wie kleine Papierfetzen vom Wind über die Weidenkoppeln getrieben. Setzt man jedoch die abgestorbenen Halme zu Komposthaufen auf, so verrotten sie sehr schnell und bilden ein lockere, humose, sehr wohlriechende Erde. Wir haben diese Kompostbereitung seit 1947 systematisch durchgeführt und sie seit 1949 für Saat- und Pflanzversuche verwandt.

Es wurden in dieser Erde Aussaaten von Stauden, Sommerblumen und von anspruchsvollen Gartengemüsen gemacht und die Sämlinge darin weiter kultiviert. Das vegetative und generative Wachstum war auffallend üppig; die Blütenfarben z.B. bei *Aster alpinus* *Primula veris* und *Trollius europaeus* waren tiefer und leuchtender als die der Vergleichspflanzen. Während aber das Blattwachstum bei *Tropaeolum maius* in dieser Erde besonders üppig war, zeigten die Blüten keinerlei Veränderungen. Hingegen waren bei *Tagetes erecta* Blätter und Blüten auffallend groß.

Die beigefügten Fotos verdeutlichen die auffallenden Größenunterschiede im Blattwachstum bei *Tropaeolum maius* (Abb. 1) und im Blatt- und Blütenwachstum bei *Tagetes erecta* (Abb. 2).

## Erläuterung zu Abb. 1:

Bezeichnung: links und rechts Riesenformen der Blätter von *Tropaeolum maius* (a-Formen).

In der Mitte: Normale Form (n-Formen).

Standort: Klostergarten Preetz/Holstein.

Erde: n-Formen: Gartenerde (humoser Lehm Boden)  
a-Formen: Kompost aus Halmen von *Scirpus lacustris*.

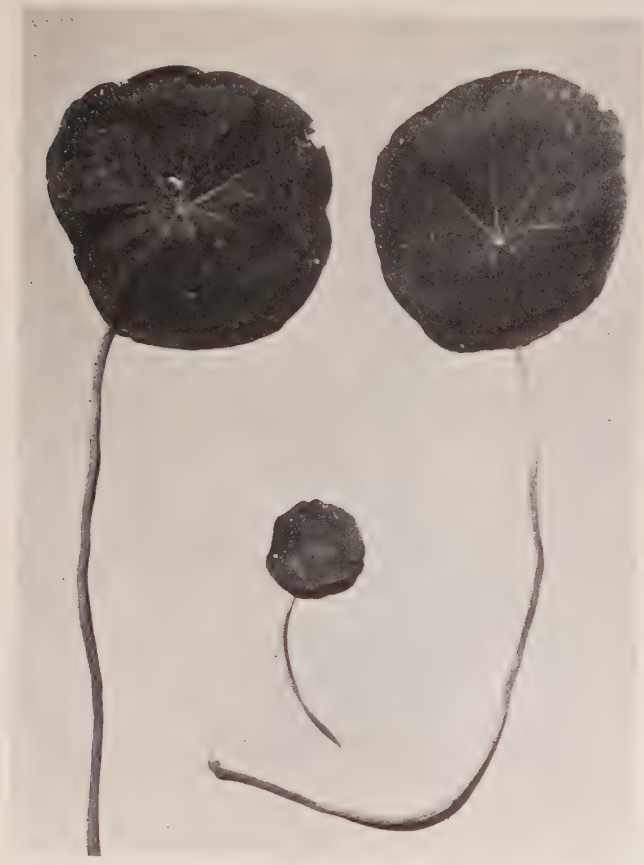


Abb. 1

Entfernung der beiden Standorte voneinander: 5 m.

Aussaat am: 1. Mai 1951.

Gemessen am: 4. Oktober 1951.

	links	Blatt	
		Mitte	rechts
Stiellänge in cm	51,4	19,2	64,2 <sup>1)</sup>
Stiieldicke in mm, Basis	9,0	2,9	11,7
Stiieldicke in mm, Spitze	3,8	1,9	3,9
Blattbreite in cm	18,2	6,6	19,4
Blattfläche in qcm	260,023	34,197	295,442

<sup>1)</sup> Im 12, 11-1952 würden Stiellängen bis 70,2 cm gemessen.



## Erläuterung zu Abb. 2:

Bezeichnung: links Riesenform von *Tagetes erecta* rechts normale Form von *Tagetes erecta*.



Abb. 2

Standort: Klostergarten Preetz/Holstein.

Erde: n-Formen: humoser Lehm Boden; a-Formen: Kompost von *Sc. lac*.

Entfernung der beiden Standorte voneinander: 2 m.

Ausgepflanzt am: 2. Juni 1951.

Gemessen am: 4. Oktober 1951.

In den folgenden Jahren wiederholten wir die Versuche und es seien hier auffallende Merkmale von *Tropaeolum maius* wiedergegeben:

Der Blattstiel ist unifacial mit Dorsal- und Ventralmedianus (TROLL 1948, S. 316). Er weist aber bei den a-Formen eine kolbenförmige Verdickung an der Stielbasis und eine Zuspitzung am Übergang zur Blattspreite auf. Diese Veränderungen konnten bei den n-Formen nirgends beobachtet werden (Abb. 3).

Die Epidermis des Blattstieles ist bei den a-Formen stark verändert. In vielen untersuchten Exemplaren sind die Zellen bedeutend kleiner, sind aber in viel größerer Anzahl vorhanden. In

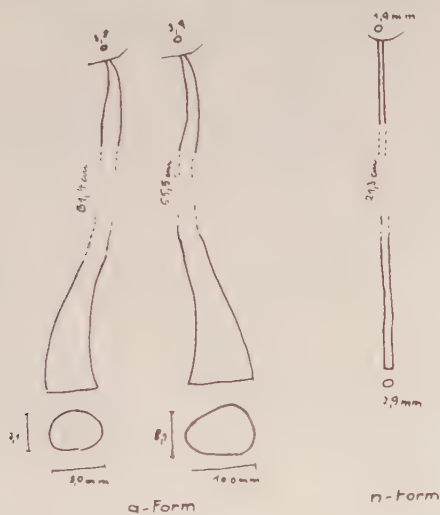


Abb. 3

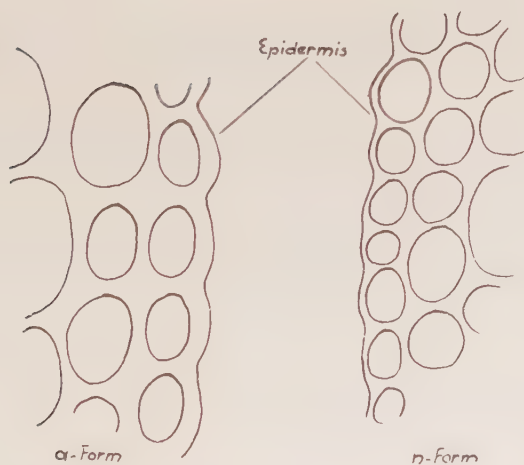
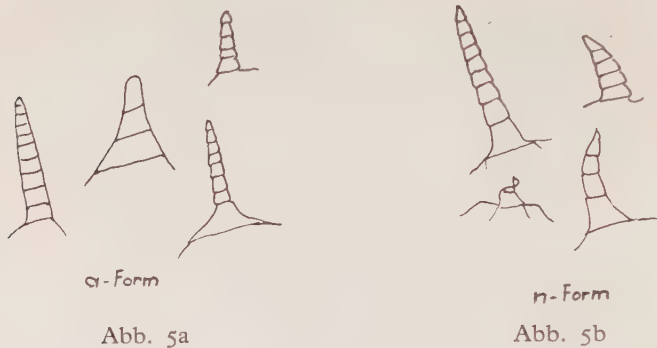


Abb. 4

allen Fällen waren bei den a-Formen die Zellwände der Epidermis sehr stark verdickt. Das sich anschließende Parenchym zeigte bei den a-Formen eine größere Regelmäßigkeit als bei den n-Formen (Abb. 4).

Die *Lamina* hat in beiden Fällen die Schildform mit nahezu zentralen Stielenansatz. Abnorme Blattbildungen, wie sie bei *Tropaeolum maius* oft beobachtet werden (siehe auch HEGI IV/3 S. 1729) entwickelten sie in keinem Fall. Die Anzahl der fast radialen Hauptnerven ist trotz des erheblichen Größenunterschiedes der a- und n-Formen nicht unterschiedlich. Es muß sich also das intercostale Spreitenbereich stark auswachsen. In der Dicke der *Lamina* konnte bei beiden Formen kein Unterschied festgestellt werden. Die in Größe und Gestalt sehr unterschiedlichen Blatthaare wurden in beiden Fällen gefunden (Abb. 5a und 5b). Während bei einigen



Messungen die Anzahl der Blatthaare bei den a-Formen stark überwogen, waren es bei anderen Messungen gerade die geringe Anzahl der Haare, die bei diesen Formen auffielen.

Das üppige vegetative Wachstum aber auch die auffallende generative Entwicklung bei Pflanzen vom *Scirpus-lacustris*-Humus, veranlassten uns, die Erde zu untersuchen <sup>1)</sup>.

Es liegen bisher folgende Analysen vor: (Unters. 17.6.52)		
Phosphorsäure ( $P_2O_5$ wurzellöslich nach Neubauer		
mg in 100 g Boden .....	20,4	
Kali ( $K_2O$ ) wurzellöslich nach Neubauer		
mg in 100 g Boden .....	57,0	
Kalk (Anfangs-pH-Zahl (Säurezahl)		
in n-KCl Aufschlammung .....	7,0	
Stickstoff nach Hasenbäumer .....	12,3	mg
Gesamt-Kupfer (Cu) .....	90	ppm
Austauschbares Mangan (sofort verfügbares Mangan)	47,4	ppm
Leicht reduzierbares Mangan (in Kürze unter Mitwirkung biochemischer Faktoren verfügb. Res. ..	119,6	ppm

<sup>1)</sup> Ich verdanke diese Untersuchungen der Zusammenarbeit mit Frl. Dr. BONIG, Landw. Unters.- u. Forschungsanstalt Kiel.

Zum Vergleich seien Neubauer-Zahlen für Phosphorsäure und Kali, Landw. Versuchs- und Forschungsanstalt Augustenberg, angegeben:

	mg $P_2O_5$ /100 g Boden	mg $K_2O$ /100 g Boden
guter Sandboden	5,0—6 9	15,0—19,9
guter sandiger Lehm Boden	6,0—7 9	22,0—29,9
guter toniger Lehm Boden	7,0—8,9	28,0—39,9

Auffallend hoch ist der Anteil der Spurenelemente Kupfer und Mangan in dieser Erde aus verrotteten *Scirpus-lacustris*-Halmen. Die Untersuchungen werden fortgesetzt.

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# Corixa lacustris Macan a synonym of *C. dorsalis* Leach

T. T. MACAN

MACAN (1954), after a visit to Denmark, concluded that the species known there as *Corixa striata* (L.) was not the same as the species known under that name in the British Isles. The Linnean type material being unsatisfactory, he applied the name *striata* (L.) to the species represented by the Danish specimens, since they agreed with the first modern description of *Corixa striata* (L.), that of JACZEWSKI (1924), and for the apparently new British species he created the name *C. lacustris*. Though no description of the differences between the two species had been made before, the new name has proved to be unnecessary. In 1817 LEACH described *Corixa dorsalis*, the type of which was later lost. However, when Dr. JACZEWSKI visited the British Museum, he examined the collection of STEPHENS, who was contemporary with LEACH, and found in it many specimens with LEACH's names, among them *C. dorsalis*.

This was regarded as a synonym of *C. striata* LINNAEUS (China, 1938). I overlooked this paper when naming *C. lacustris* and the error did not come to light till Dr. CHINA was putting my supposed type specimen into the British Museum collection. Then it occurred to him that it was probably identical with *C. dorsalis* LEACH of which, he tells me, JACZEWSKI „in effect selected a neotype”. An examination soon revealed that this specimen agreed with *lacustris* rather than *striata* (L.). The synonymy is therefore:

*Corixa dorsalis* LEACH 1817

*Sigara striata* CHINA 1938 not (LINNAEUS 1758)

*Corixa lacustris* MACAN 1954

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## Personalia

### Prof. O. Haempel zum Gedächtnis

Am 2. Januar 1953 verschied nach kurzem schweren Leiden der bekannte österreichische Fischereibiologe Prof. Dr. OSKAR HAEMPEL im 71. Lebensjahre.

Er war ein Schüler des Altmeisters der Fischereibiologie Prof. HOFER, als dessen Assistent er nach Vollendung seiner Studien an der Bayrischen Biologischen Versuchsanstalt in München tätig war. Von hier ging er dann nach Wien, wo er sich 1909 an der Hochschule für Bodenkultur als Privatdozent für das Fach Hydrobiologie und Fischereiwirtschaft habilitierte. Im Jahre 1920 erfolgte gleichzeitig mit der Verleihung des Titels eines ausserordentlichen Professors seine Berufung an die neugegründete Lehrkanzel für Hydrobiologie an dieser Hochschule. 1928 übernahm er noch die Leitung der vom ihm begründeten Fischereibiologischen Bundesanstalt in Weissenbach am Attersee.

Von seinen zahlreichen Veröffentlichungen aus nahezu allen Gebieten der Hydrobiologie und Fischereiwirtschaft sind die bekanntesten der „Leitfaden der Biologie der Fische“ (1912), das „Handbuch der Fischereibetriebslehre“ gemeinsam mit DOLJAN (1921) und die „Biologie der Alpanseen“ (1930).

In den letzten Jahren befasste er sich besonders mit dem Studium der Wirkung von Hormonen auf Fische und war noch in seinen letzten Lebenstagen auf diesem Gebiete forschend tätig.

Nicht nur den Forscher HAEMPEL werden alle, die ihn kannten, in ehrenvollem Andenken behalten sondern ebenso den stets hilfsbereiten und verständnisvollen Berater und Freund.

K. STUNDL

# Fresh-water Invertebrates of the United States

By ROBERT W. PENNAK.

The Ronald Press Co., New York, 1953. 769 pages.

It is curious to see how difficult it is for the limnologists of North America and Europe to acquire a thorough knowledge of each other's scientific literature. An example will show the correctness of this view: In PAUL S. WELCH's second edition of „Limnology” 1952, 88% of the literature quoted is written in English, and in FRANZ RUTTNER „Grundriss der Limnologie” 1952, 80% is written in German. It is, therefore, important to call the attention of European readers to a new, valuable, and handsome treatise by Professor PENNAK, a pupil of the late Professor C. JUDAY, Wisconsin. His book is of particular interest to American biologists and zoologists, but also to Europeans, since every chapter dealing with the various groups of fresh-water animals has a general biological and morphological introduction, summarizing classical and recent investigations; and among the latter are many important American papers published during the war-time or later, and as yet not very well known in Europe.

The general characteristics of each group of animals are clearly stated, and the account comprises a morphological description, locomotion, feeding, internal anatomy, reproduction, seasonal variation of numbers, developmental life cycle, general ecology, geographical distribution, economic significance, taxonomy etc. It concludes with a key to the species or genera. Of course the key cannot give the species for all large groups where the taxonomy is still vague, but in such cases it is limited to the genera. There are more than 2000 good, instructive figures, which facilitate the determination.

It is very difficult for one author to write about all fresh-water groups from Protozoa to Molluscs, but Professor PENNAK seems to have overcome all difficulties in this respect; he has had his manuscript carefully criticized and corrected by a great number of helpful specialists.

The excellently written text and the beautiful get-up of the book constitute a plea for and an encouragement to more limnological work on the fresh-water fauna in North America. The book will also be a valuable addition to the library of European limnologists. KAJ BERG

# Hydrobiologia ogólna

A. LITYNSKI

Warszawa, PAŃSTWOWE WYDAWNICTWO NAUKOWE, 1952, 545 p p.,  
277 figs., portrait de l'auteur (en langue polonaise).

Table des matières (pp. 21 - 506, chapitres I - X): Introduction. Hydrosphère comme milieu de vie des êtres vivants. Régions biologiques de l'eau. Organismes aquatiques et le milieu physique. Lumière comme facteur écologique. Bilan thermique des eaux et son importance pour la vie des êtres vivants. Régime gazeux de l'hydrosphère. Relation entre les êtres vivants et les sels minéraux dissouts dans l'eau. Rôle des composants nutritifs dissouts dans l'eau pour les êtres aquatiques. Productivité biologique des eaux.

L'auteur de la note présente a fait précéder le texte proprement dit par une préface, un bref curriculum vitae et une bibliographie complète des travaux scientifiques de A. LITYNSKI. C'est par lui, que le livre complété par les données hydrobiologiques plus récentes et pourvu d'illustrations, a été préparé a la publication. Malgré ces suppléments la disposition primaire du matériel et les idées fondamentales de LITYŃSKI ont été conservées, sans changements. Le livre de A. LITYŃSKI est écrit avec beaucoup de talent. LITYŃSKI était pendant de longues années directeur de la Station Hydrobiologique du lac de WIGRY et en outre un savant plein de mérite, car il a contribué au développement des recherches hydrobiologiques en POLOGNE. C'est une tentative hardie de réunir dans une seule oeuvre tous les problèmes hydrobiologiques fondamentaux concernant les eaux douces et salées. En comparant les résultats des recherches des deux branches essentielles d'hydrobiologie et notamment de limnologie et d'océanologie, l'auteur à maintes reprises arrive à des conclusions intéressantes et originales. Le livre contient un matériel, abondant résultat des recherches hydrobiologiques polonaises, mais comme on peut se rendre compte aisément en examinant la littérature, les idées et les considérations de l'auteur se basent sur les acquisitions mondiales dans le domaine de l'hydrobiologie.

Nous devons à l'effort créateur de LITYŃSKI l'originalité de cette oeuvre hydrobiologique intéressante qui rendra un très grand service non seulement aux étudiants, mais aussi aux spécialistes.

L. K. PAWLOWSKI



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Number of the sample	A008	A009	A010	A011	A012	A013	A014	A015	A019	A021	A024	A025	A027	P.-ice
Sampling spots, dates and details	25-12-1946 55° 44' S, 6° 40' E SE Bouvet island	30-1-1947 64° 29' S, 9° 29' W Depth 0-5 m Daytime	30-1-1947 64° 29' S, 9° 29' W Depth 0-5 m? At night	31-1-1947 64° 29' S, 9° 39' W Depth 100-150 m Daytime	1-2-1947 63° 57' S, 10° 25' W no further details	1/2-2-1947 63° 50' S, 10° W Depth 100-150 m At night	2-2-1947 63° 50' S, 10° W Depth 100-150 m Daytime?	2-2-1947 63° 50' S, 10° W Depth 100-150 m Midday	3-2-1947 64° 51' S, 10° 50' W Depth? Midday + evening	5-2-1947 64° 38' S, 11° 26' W Depth 150-75 m epoch?	18-2-1947 65° 15' S, 10° 58' W Depth 500-250 m Midday	18/19-2-1947 65° 14' S, 10° 58' W Depth? At night	25-2-1947 66° 50' S, 11° W Depth 900-0 m Midday	21-2-1947 ± 66° 50' S, 11° W
Species														
<i>Asteromphalus brookei</i> Bail.	rr													
<i>A. humboldti</i> Ehr.	r	rr			rr	rr			rr	rr	rr	rr		rr
<i>A. ralfsianus</i> (Norm.) Grun.													rr	rr
<i>A. spec.</i>	rr													
<i>Chaetoceros criophilus</i> Castr.	c	+	cc *	rr	cc *	r	+	r	r	r	r	r	r	
<i>Ch. dictyota</i> Ehr.	c	+	cc *	rr		r			r	r	r	r	+	cc
<i>Corethron valdiviae</i> Karst.	rr													cc
<i>Coscinodiscus bifrons</i> Castr.?						rr								rr
<i>C. lentiginosus</i> Jan.						rr	rr	rr	rr	rr				
id. var. <i>confusus</i> V.H.	rr													
<i>C. rotula</i> Grun.?		rr												
<i>C. spec.</i>				r	rr	rr	rr	rr						
<i>Dactyliosolen antarcticus</i> Cast.														rr
<i>Eucampia antarcticum</i> Cast.	rr													
<i>Fragilaria castracanei</i> De Toni	c	r	rr	rr	r	c	r	rr	+	+	+	+	rr	+
<i>F. cylindrus</i> Grun.	+	rr	rr	rr	rr	+	rr	rr	r	r	r	r	rr	rr
<i>F. spec.</i>	rr			r		+			rr	rr			rr	
<i>Navicula spec.</i>	rr													
<i>Nitzschia punctata</i> (W. Sm.) Grun.						+	rr		rr	rr	rr	rr	rr	rr
<i>N. seriata</i> Cl.	+													
<i>N. tryblionella</i> Hantzsch. var. <i>debilis</i> (Arn.) Meyer	+			rr										
<i>Rhizosolenia alata</i> Brightw. fo. <i>inermis</i> Castr.	r		r	rr	+	r	rr	rr	rr	rr	rr	rr	rr	
<i>R. styliformis</i> Brightw.	rr							rr						
<i>Stephanopyxis</i> (type <i>brüni</i> A. S.)				rr										
<i>Synedra reinboldi</i> V. H.														
<i>Thalassiothrix longissima</i> Cl. & Grun.	c	+	cc	r	+	r	+	r	r	r	r	r	cc	c

rr = very small  
r = small number

+ = moderate number

c = great number  
cc = very abundant

\* fragments and loosed spines

B

V

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J

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# SYMPOSIA

of the

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